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ACOUSTIC ANALYSIS OF THE DEFENSIVE SOUNDS OF *VARANUS SALVATOR* WITH NOTES ON SOUND PRODUCTION IN OTHER VARANID SPECIES

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(with eight text-figures)

ABSTRACT.- The hiss and other defensive sounds were analyzed from 16 specimens of *Varanus salvator*, and from representatives of 13 additional monitor species. While there are considerable interspecific differences in the acoustic properties of the hisses, they all have simple acoustics due to the paucity of frequency modulation and temporal patterning. Observations and experimental occlusion of the external naries demonstrate that the hisses are produced through the nasal passageway. The interspecific variation observed in the acoustic profiles of the hisses may be a reflection of interspecific variation in the size and structural arrangement of the nasal passageway.

KEY WORDS.- *Varanus*, acoustics, defensive behavior, lepidosauria, hissing, respiratory morphology.

INTRODUCTION

Squamate reptiles, and especially lizards and snakes, are increasingly serving as "model organisms" for ecological studies (e.g., Huey et al., 1983; Seigel et al., 1987; Seigel and Collins, 1993). Studies on the ecology of squamate defensive behaviors are still rare, however. Although there have been reviews of squamate defensive behavior (e.g., Carpenter and Ferguson, 1977; Greene, 1988), and Mertens (1946) provided a valuable discussion of many of these behaviors; the primary literature on squamate behavior is still dominated by anecdotal accounts. The paucity of quantitative analyses is especially evident in the literature on sound production, owing to the difficulty in providing a complete and accurate verbal description of a sound.

Monitor lizards (*Varanus*) are a group of approximately 35 species which are divided into six (or seven) subgenera: two of these subgenera form the African radiation, two more constitute the Australian radiation, and the remaining subgenera form a more poorly defined Indo-Asian radiation (e.g., Mertens, 1942; King and King, 1975; Pregill et al., 1986; Sprackland, 1991; King and Green, 1993). There is considerable variation in the habitat preference, diet, and community structure of different monitor species (e.g., Auffenberg, 1981,1988; Daltry, 1991; King and Green, 1993; Lenz, 1995); and interspecific variation exists in the tendency to exhibit defensive displays and to vocalize (e.g., Carpenter and Ferguson, 1977; Greene, 1988; Bennett, 1995; De Lisle, 1996).

The ability of monitor lizards to produce sound has been frequently noted — for example, Stirling (1912) described the sound produced by *Varanus giganteus* as a, "continuous blowing sound like that of a blacksmith's bellow"- however, these sounds have never been quantified. The influence of acoustic stimuli on varanid behavior is unclear. Several workers (e.g., Waite, 1927; Collins, 1956) have claimed that monitors are deaf, while others (Lederer, 1942; Pfeffer, 1959) have trained monitors to respond to acoustic stimuli. Several reviews of reptilian sound production and acoustic communication are available (Mertens, 1946; Gans and Maderson, 1973; Frankenberg and Werner, 1992; Young, 1997a,b), yet this aspect of reptilian behavior is still relatively unknown, as evidenced by the recent discovery of a "vocal cord" in a snake (Young et al., 1995).

A series of recent papers have detailed a variety of sound production mechanisms in snakes (Kinney et al., 1998; Young, 1991; Young and

Brown, 1993, 1995; Young and Lalor, 1998; Young et al., 1995). In a recent review Young (1997a) hypothesized that snakes may lack intraspecific acoustic communication simply because it was absent in their evolutionary ancestor. Among living squamates the Varanidae are generally taken to be the sister taxa of snakes (Estes et al., 1988; Lee, 1997), thus an analysis of acoustic communication among monitors would provide a phylogenetic framework for understanding ophidian acoustics. The current study has two main goals: to provide an initial acoustic survey of the defensive sounds produced by monitors, and to document any acoustic properties which could be correlated to morphological or behavioral specializations such as throat expansion (Bels et al., 1995).

MATERIALS AND METHODS

Morphology of the upper respiratory tract.- The nasal passageway and upper respiratory tract were dissected in the following juvenile or adult specimens from the personal collection of BAY: *Varanus dumerili*, *V. indicus* and *V. salvator*. A portion of the nasal epithelium was removed from an adult (73 cm SVL) specimen of *V. salvator*. This tissue was dehydrated through an alcohol series, cleared in Hemo-De (Fisher), and embedded in paraffin. Transverse sections were cut at 10μm and stained with hematoxylin and eosin as well as Masson's trichrome (Luna, 1968).

Acoustic analysis of *Varanus salvator*.- Fourteen specimens of *V. salvator* were isolated within large outdoor enclosures at the Centre for Herpetology, Madras Crocodile Bank Trust. With each specimen unrestrained defensive behaviors were induced and recorded using a Fostex X-18 recorder (frequency response 50-12,000 Hz) and a ND 757B (ElectraVoice) microphone positioned approximately 40 cm from the animals head. Amplitudes of the defensive sounds were determined using a 840029 Digital Sound Meter (SPER Scientific). Recordings were analyzed using an Instrunet Analog/Digital converter (GW Instruments), Power Macintosh 8500 (Apple Computer), and the SoundScope software package (GW Instruments). Analyses were done at a sampling rate of 44.1 kHz, a Fast Fourier Transformation (FFT) using 2048 points, and a 59 Hz filter. Background sounds were obtained for each recording session and were filtered from the data using the WLFDAP 1.0 (Zola Technologies, Atlanta, GA) digital filtration software.

At least six defensive hisses were recorded from each specimen. For each sound the duration, maximum amplitude, dominant frequency, minimum frequency, and maximum frequency were quantified: frequency values were determined using spectral analysis. Each sound was also examined for amplitude or frequency modulation, as well as harmonics.

Acoustics of other varanid species.- The other live monitor specimens examined for this study — *Varanus acanthurus* (SVL = 18 cm); *V. albigularis* (SVL = 30 and 68 cm); *V. doreanus* (SVL = 29 cm); *V. exanthematicus* (SVL = 40 cm); V. gouldii (SVL = 33 cm); *V. jobiensis* (SVL = 22 cm); *V. niloticus* (SVL = 27 cm); *V. rudicollis* (SVL = 52 cm); *V. salvator* (SVL = 30 and 73 cm); *V. timorensis similis* (SVL = 23 cm)- were obtained from commercial dealers or from the private collection of BAY. The animals were kept either loose, or in large terraria, within a room designed to house reptiles. The animals were maintained at 30°C, a 12:12 light cycle, water ad libitum, and a diet of rodents. A 75 cm SVL specimen of *V. komodoensis* was examined at the U.S. National Zoo; in addition, three specimens were examined at the Philadelphia Zoo (51 cm SVL *V. bengalensis*; 22 cm SVL *V. prasinus*; and 69 cm SVL *V. salvadorii*). The varanid nomenclature used herein is based on the recent works by Bennett (1995) and De Lisle (1996).

Depending on size and activity these specimens were either placed on a table or turned loose within a warm (29-31°C) quiet room; all recordings were taken with the animals unrestrained. Recordings from zoo animals were taken with the animals inside large enclosures. The defensive behaviors were normally evoked simply by the presence of the investigators. Defensive sounds were recorded with an ElectraVoice RE 55 microphone (frequency response 50-20,000 Hz) positioned within 40 cm of the animals head. The microphone was attached to a SONY TC-

277 reel-to-reel tape deck. Acoustic analyses were performed as detailed above.

Narial occlusion.- To determine the influence of nasal passage morphology on the defensive sounds selected specimens of *Varanus albigularis, V. gouldii* and *V. niloticus* were briefly restrained and their external nostrils partially or completely plugged by the insertion of a small ball of sterile cotton which was covered by a piece of surgical tape. The animals were released and subsequent defensive sounds, if any, were recorded. The nasal plugs were removed from the animals within a 15 minute period.

RESULTS

Anatomy of the upper respiratory tract in *Varanus*.- The arytenoid cartilages are pronounced in *Varanus*, and cover the craniodorsal and craniolateral portions of the cricoid cartilage. Ventrally the inferior median eminence of the cricoid extends cranially between the contralateral arytenoids. On the inner surface of the larynx the anterior margin of the cricoid forms a very slight ridge where it terminates along the medial surface of the ipsilateral arytenoid cartilage (Fig. 1C). The varanid larynx is devoid of both internal partitions and diverticulae.

The nasal passageway of the monitors examined differ in relative proportions and shape; the following is intended only as a generalized description. The orbitonasal trough in *Varanus* is shallow and indistinct. The internal naries (choanae) are ovate and lead into the short craniodorsal choanal tube (Fig. 1A). The lateral wall of the choanal tube supports a slight expansion, the lateral choanal fissure. Dorsal to the lateral choanal fissure, the lateral recess opens into the choanal tube. The lateral recess expands caudolaterally forming a distinct sinus within the maxilla. The dorsal opening of the choanal tube is marked cranially by a pliable horizontal shelf of tissue and caudally by the projecting tip of the concha (Fig. 1A,B). The cavum nasi proprium extends caudomedially before making a lateral deflection at the caudal end of the concha. Throughout its length the cavum nasi proprium is narrow, but deep (Fig. 1B).

Immediately cranial to the dorsal end of the choanal tube the diameter of the vestibulum reduces (Fig. 1D). The tissue in this area is richly vascularized due to the pronounced sinus vestibuli nasi (Bruner, 1907). Cranial to this patch of vascular tissue the diameter of the vestibulum expands. The vestibulum extends cranially then arches laterocaudally to form the external naries (Fig. 1B). In the live specimens examined the external naries varies from an elongate horizontal slit in *Varanus rudicollis* (Fig. 1E), a posteriorly directed vertical cleft in *V. exanthematicus*, to a rounded slightly elevated opening in *V. gouldii* (Fig. 1F).

General description of the defensive behaviors.- Considerable variation was present in the defensive behaviors of the species examined. Hissing was the only defensive behavior common to every specimen; however, *Varanus rudicollis* and *V. doreanus* would only hiss when exposed to very specific stimuli. *V. rudicollis* had a strong tendency to "freeze" or death feign- this specimen would only hiss if kept elevated and the harasser maintained a distance of several meters. In contrast, the dominant defensive behavior in *V. doreanus* was nearly continuous mouth gaping and attempts to bite. This specimen would only hiss if approached slowly: normally after producing a single hiss the specimen would adopt and maintain a mouth open posture for the remainder of the recording session. The remaining specimens all hissed repeatedly. Some (*V. albigularis, V. exanthematicus, V. gouldii, V. komodoensis* and the larger specimens of *V. salvator*) remain nearly stationary while hissing, while the remaining species intermix hissing with attempts to flee. Four other defensive behaviors- mouth open gaping, inflation of the throat region, inflation of the thorax, and tail whipping- while frequently observed, were not consistently associated with sound production.

All of the species we examined produced defensive sounds in at least one of six different ways: hissing, during inhalation, by opening the mouth, through apposition of the arytenoid cartilages of the larynx, by making contact with the tail, and during evacuation of the cloaca. The last two means of sound production, while commonly observed, were deemed too "substrate specific" for the current analysis.

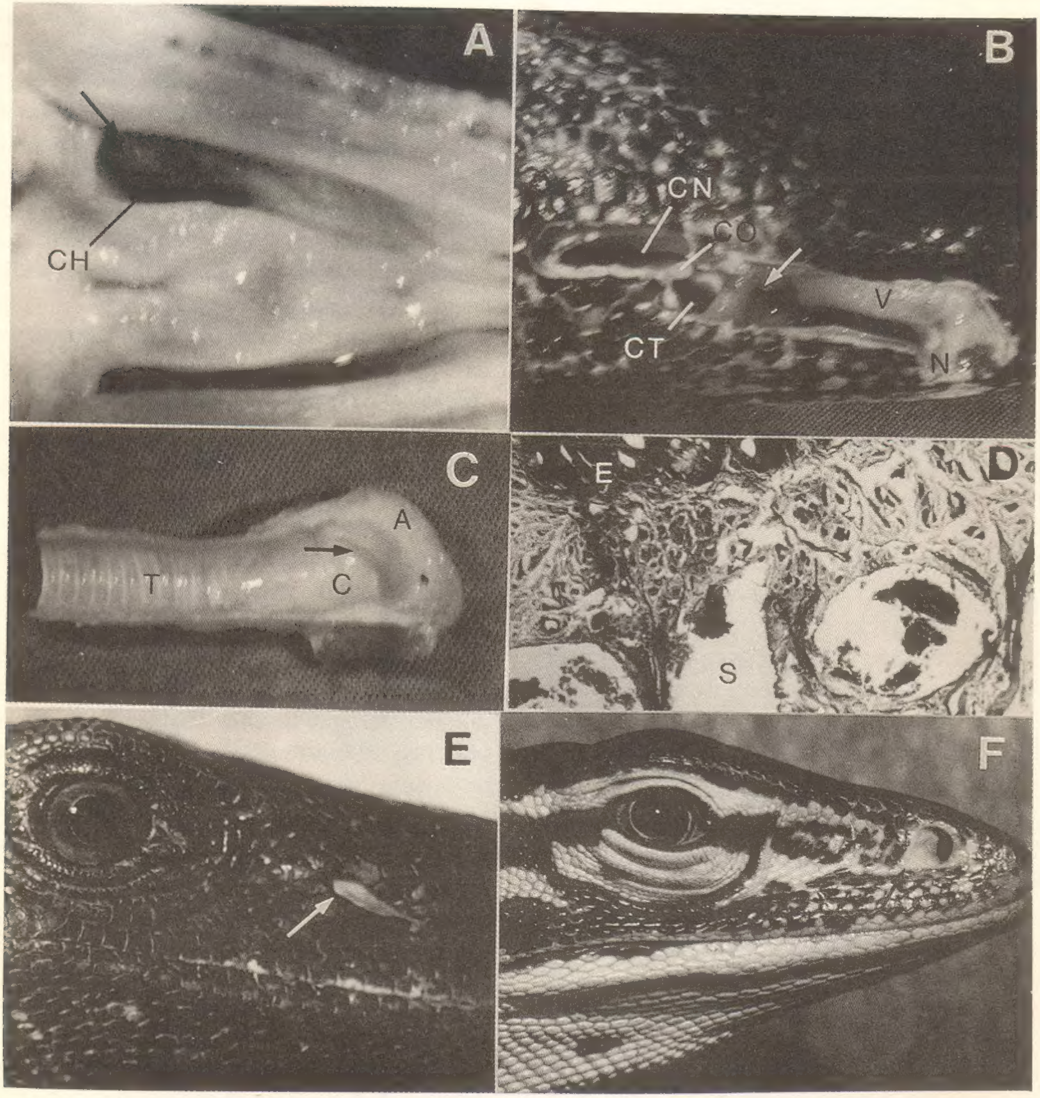

FIGURE 1: Morphology of the upper respiratory tract of *Varanus*. A - ventral view of the palate of *V. salvator* showing the internal nare (choana) and the position of the opening to the lateral sinus (arrow); B - dorsal view of the snout of *V. salvator*, the dorsal covering of the nasal passageway has been removed to show general shape and position of the nasal passageway, note the band of richly vascularized tissue (arrow); C - parasagittal section through the excised larynx of *V. salvator*, note the absence of any vocal cord and the presence of a low ridge (arrow) along the anterior margin of the cricoid; D - transverse section through the caudal portion of the sinus vestibuli nasi of *V. salvator*, note the abundant vasculature and the radially arranged connective tissue elements (arrow); E - external naries of *V. rudicollis*, note that in this species the external naries takes the form of an elongate horizontal slit (arrow); F - external naries of *V. gouldii*, note the circular shape and relatively large diameter of the naries (arrow). Abbreviations: A - arytenoid cartilage; C - cricoid cartilage; CH - choana; CN - cavum nasi proprium; CO - concha; CT - choanal tube; E - epithelium; N - external naries; S - sinus vestibuli nasi; T - trachea; V - vestibulum.

The hiss of *Varanus salvator*.- The 16 specimens examined ranged in snout-vent length from 36-94 cm with a mean SVL of 59.2 cm. Over 90 hisses were analyzed, these had a mean duration of 2.5 sec (s.d. = 1.3 sec) and a mean maximum amplitude of 64.2 dB (s.d. = 6.1 dB). Larger monitor lizards produce significantly longer hisses (t-test = 5.05, p 0.05, df = 14). The hiss of *V. salvator* is acoustically simple, lacking any distinct frequency modulations or harmonics. Episodic amplitude modulation was detected in some hisses, but was not a regular feature of this defensive sound. The hiss of *V. salvator* has a mean minimum frequency of 430 Hz (s.d. = 201.9 Hz), a mean dominant frequency of 4591.8 Hz (s.d. = 1214.2 Hz) and a mean maximum frequency of 9945.4 Hz (s.d. = 2302.3 Hz) (Fig. 2).

Larger specimens of *Varanus salvator* produced hisses with significantly lower minimum frequencies (t-test = 2.23, 14 df), but with dominant and maximum frequencies similar to those of smaller specimens. Hisses with higher amplitudes had significantly higher dominant (t = 5.61, 14 df) and maximum (t = 2.37, 14 df) frequencies; although there was no significant relationship between hiss amplitude and either minimum frequency or hiss duration. The minimum and maximum frequencies of the hisses were significantly related (t = 2.87, 14 df) as were the dominant and maximum frequencies (t = 2.24, 14 df). No significant relationship was found between the minimum and dominant frequency of the hiss, nor was there any significant relationship between the duration and frequency profile of the hiss.

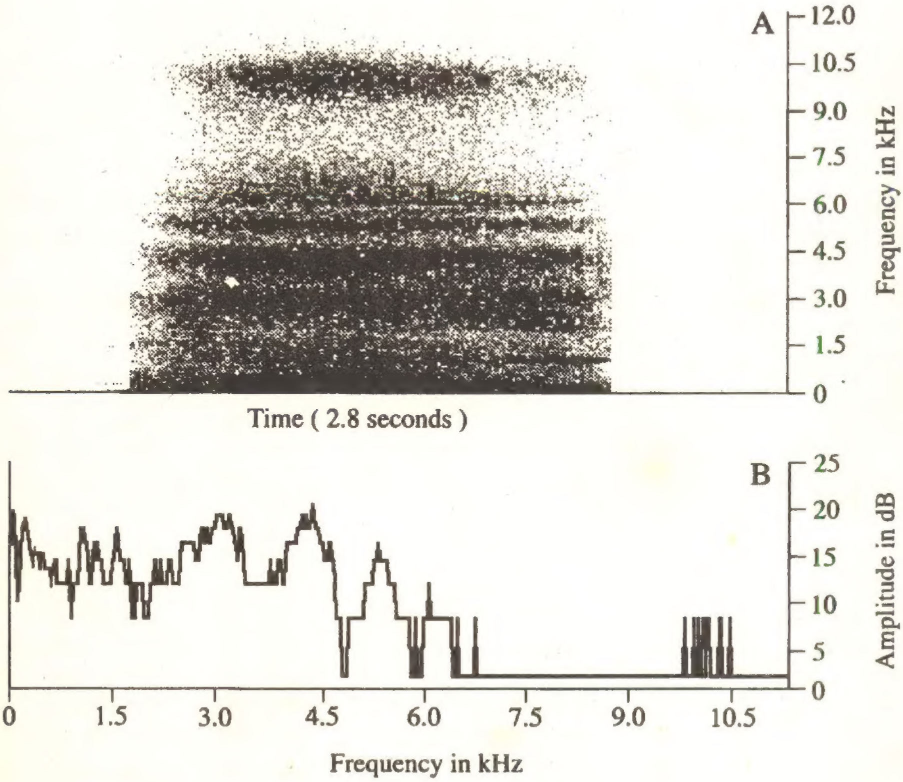

FIGURE 2: Acoustic properties of a 2.8 second hiss from a 94 cm specimen of *Varanus salvator*. A - sonogram of the hiss; Y - axis is frequency in kHz, X - axis is time, and increasing amplitude is denoted by relative darkness. B - Power spectrum analysis of the same hiss (performed with an FFT of 2048 points); Y - axis is amplitude in dB, X - axis is frequency in kHz.

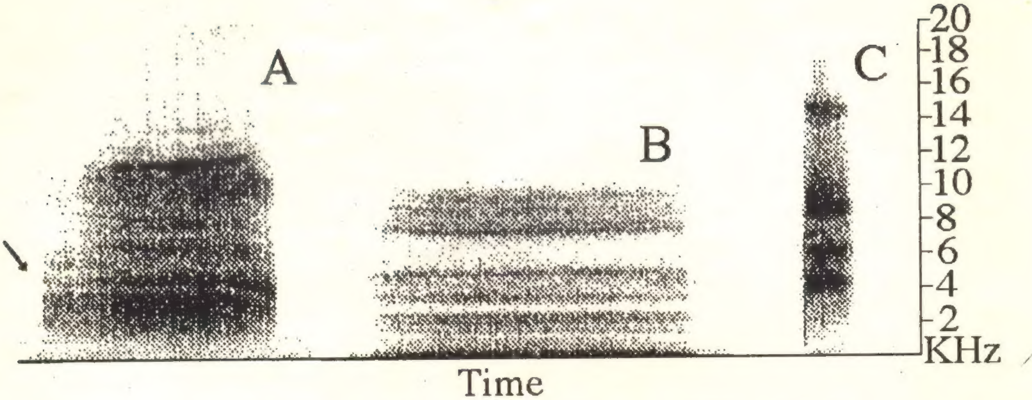

FIGURE 3: Sonogram showing the three "types" of hisses observed in *Varanus*; Y-axis is frequency (in kHz), X-axis is time, and increasing amplitude is denoted by relative darkness. A - a 3.5 sec hiss from *V. albigularis*, note the relative even amplitude distribution among the frequencies and the presence of an acoustic "shoulder" in the early portion of the hiss (arrow); B - a 4.4 sec hiss from *V. bengalensis*, note the prominent low amplitude frequency bands in the center of the hiss; C - a 0.6 sec hiss from *V. salvadorii*, note the large frequency span and

Hissing in other varanids.- The varanid hisses all cover a broad span of frequencies, from a low of less than 9,000 Hz in *Varanus bengalensis, V. exanthematicus, V. komodoensis* and *V. prasinus* to a high of approximately 18,000 Hz in *V. gouldii* (Fig. 3, Table 1). Although there are intermediate gradations, these hisses can be divided into three different "types"(Fig. 3): long-duration hisses in which the frequencies have similar amplitudes (*V. albigularis, V. gouldii, V. niloticus* and *V. salvator*)(Fig. 3A); hisses with "frequency gaps" due to low amplitude frequencies (*V. bengalensis, V. exanthematicus, V. komodoensis* and *V. prasinus*)(Fig. 3B); and short-duration hisses with broad frequency span (*V. acanthurus, V. doreanus, V. jobiensis, V. rudicollis, V. salvadori* and *V. timorensis*)(Fig. 3C). In the hisses of longer duration, there is

TABLE 1: Summary statistics for the hiss of *Varanus*. SVL = snout-vent length in cm; # = number of hisses recorded; frequency values are in hertz, amplitude values in dB, and duration in seconds. All values given are in the format of mean (standard deviation). Values presented for *V. salvator* are data pooled from all 16 specimens.

Species	SVL	#	Duration	Maximum Amplitude	Minimum Frequency	Dominant Frequency	Maximum Frequency
V. acanthurus	18	28	0.99 (0.36)	64.3 (3.5)	798 (138)	5042 (1405)	18206 (477)
V. albigularis	30	22	3.39 (0.6)	74.6 (3.7)	431 (135)	3191 (367)	12327 (1009)
V. albigularis	68	10	6.09 (1.86)	71.5 (5.9)	273 (35)	3053 (950)	15860 (3335)
V. bengalensis	51	10	3.64 (0.93)	69.0 (2.4)	619 (64)	3252 (1349)	9566 (688)
V. doreanus	29	6	0.19 (0.08)	67.2 (2.2)	394 (105)	4756 (1033)	17675 (284)
V. exanthematicus	40	8	1.91 (0.88)	67.3 (8.2)	806 (338)	5131 (997)	9772 (3767)
V. gouldii	33	15	2.23 (0.75)	76.1 (5.0)	430 (138)	10521 (4692)	19004 (307)
V. jobiensis	22	12	0.37 (0.12)	67.5 (6.0)	1185 (261)	4216 (1392)	18344 (385)
V. komodoensis	75	16	3.25 (0.62)	71.7 (3.9)	384 (148)	3576 (490)	9077 (797)
V. niloticus	27	15	1.91 (0.59)	65.3 (7.5)	429 (299)	5405 (2006)	12002 (3375)
V.prasinus	22	8	0.57 (0.19)	66.6 (6.3)	266 (180)	1632 (992)	7403 (1728)
V. rudicollis	52	6	0.45 (0.16)	67.2 (2.2)	287 (172)	3956 (3618)	13283 (780)
V. salvadorii	69	14	0.69 (0.18)	65.8 (3.8)	756 (119)	6051 (1669)	15236 (241)
V. salvator	59	104	2.50 (1.3)	64.2 (6.1)	430 (202)	4592 (1214)	9945 (2302)
V. timorensis	23	13	0.50 (0.21)	70.6 (3.5)	543 (73)	3158 (1226)	16881 (2258)

normally an initial "shoulder" of lower frequency, lower amplitude sound (Fig. 3A). While most of the hisses have multiple frequency bands of higher amplitude, there is little evidence of harmonics within these hisses.

Most of the hisses include only slight frequency modulation, and this is normally restricted to the terminal portion of the hiss. A prominent exception is the hiss of *Varanus gouldii*, which includes an initial brief (~ 0.2 sec) period of distinct frequency modulation and harmonic structuring (Fig. 4A). Amplitude modulation is much more common and is present during every temporal portion of the hiss; periods of sharply increased amplitude are always associated with an increase in the maximum frequency of the hiss (Fig. 4B). Some of the hisses, particularly those of short duration, approach the acoustic characteristics of white noise in that every frequency has a similar amplitude and there is no distinct dominant frequency (Fig. 4C).

The hisses of all the specimens examined exhibit variation in the quantified acoustic characteristics. Figure 4D represents a 10 second

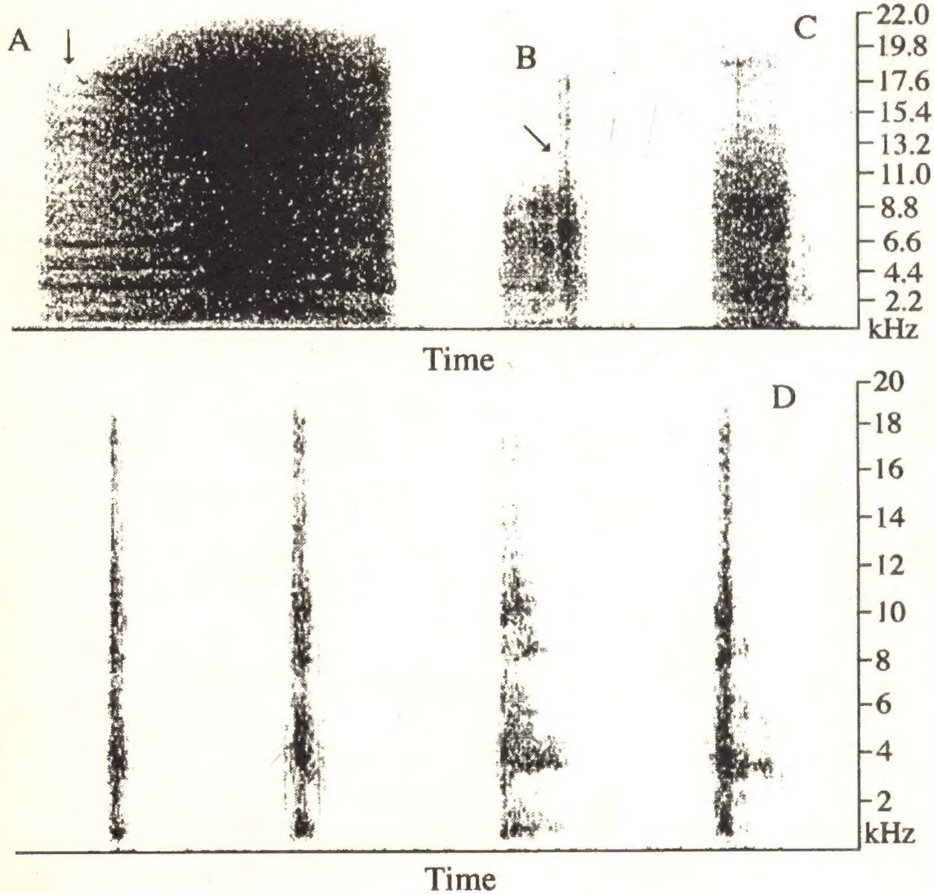

FIGURE 4: Sonogram showing variations in the hisses of *Varanus*; Y-axis is frequency (in kHz), X-axis is time, and increasing amplitude is denoted by relative darkness A - a 2.0 second hiss from *V. gouldii* showing frequency modulation (arrow); B - a 2.4 sec hiss from *V. niloticus* showing strong amplitude modulation and associated increase in maximum frequency (arrow); C - a 0.4 second hiss from *V. rudicollis*, the dominant frequency in this hiss is poorly defined and the hiss approaches white noise; D - a 10 sec recording from *V. timorensis* showing variation in four consecutive hisses.

recording of *Varanus timorensis* similis which captured four consecutive hisses- note the variation in amplitude, duration, and frequency among these hisses. The relative variation in these quantitative characters can be gauged from the standard deviations given in Table 1. This variation is pronounced in the dominant frequency. Many of the species produce hisses with two or more prominent frequency bands; the relative amplitude of these multiple frequency bands often varies between successive hisses.

Given the variation in these quantitative characters, and the nature of our data pool, a statistical test for the acoustic uniqueness of each species does not seem appropriate. Nonetheless, there is a suggestion of at least several acoustic "types" of hisses. For example, *Varanus jobiensis* and *V. doreanus* both have hisses with mean durations of 0.5 sec or less, maximum amplitudes near 67 dB, and mean maximum frequencies of nearly 18 kHz. In contrast, the hisses of *V. albigularis, V. bengalensis* and *V. komodoensis*, all have long duration (3 sec), maximum amplitudes near 70 dB, and maximum frequencies below 13 kHz. The duration of the hiss is significantly related to body size (t-test, $p = 0.006$); however the remaining differences in the acoustic properties of the hisses are not significantly related to the body size of the animal.

All the hisses were produced while the lizard's mouth was closed. In several species (e.g., *Varanus gouldii* and *V. t. similis*) there was a regular alternation of mouth-closed hissing and mouth-open gaping. No hisses were produced during mouth-open gaping. In order to determine the course of the exhalent air during hissing, the external naries were at least partially occluded in four specimens (two *V. albigularis, V. gouldii* and *V. niloticus*). Following occlusion of the external naries, *V. niloticus* produced no hisses although the remainder of its defensive behavior repertoire was unaffected. In the other three specimens occlusion of the external naries produced an alteration in the amplitude and frequency of sounds produced, although the efficacy of the occlusion was less in the larger specimen of *V. albigularis*. (Table 2; Fig. 5).

Inhalatory sounds.- Clear inhalatory sounds were recorded from most of the species; however, with the exception of the smaller specimen of *Varanus albigularis*, these sounds were only infrequently heard. Normally only a single inhalatory sound was produced between two hisses, although in *V. albigularis* inhalatory couplets were found. The inhalatory sound from *V. komo-*

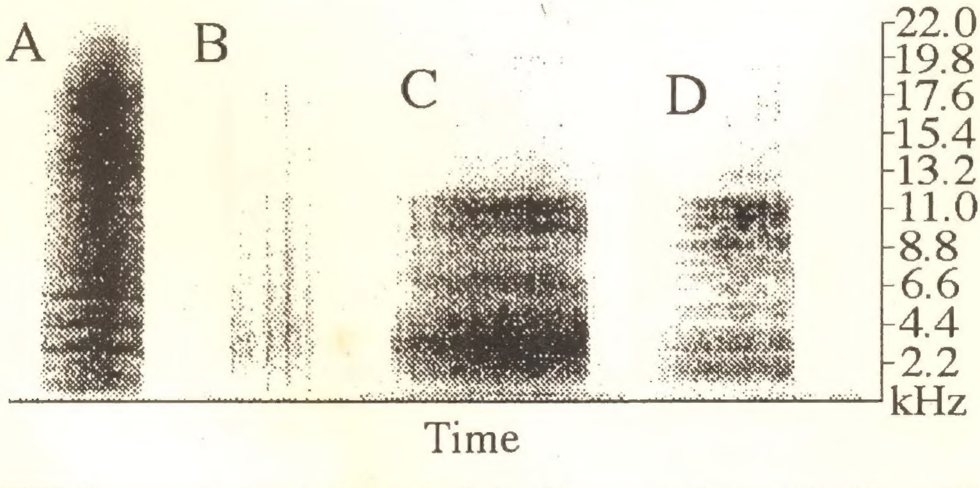

FIGURE 5: Sonograms showing the influence of occlusion of the external naries on the hiss of *Varanus*; Y-axis is frequency (in kHz), X-axis is time, and increasing amplitude is denoted by relative darkness. A - a 2.2 sec hiss from *V. gouldii* with patent external naries; B - a 2.3 sec hiss from the same specimen following occlusion of the external naries, note the change in frequency span and amplitude; C - a 3.8 sec hiss from *V. albigularis* with patent external naries; D - a 2.7 sec hiss from the same specimen following occlusion of the external naries, note the marked reduction in amplitude following occlusion of the naries.

TABLE 2: Summary statistics for varanid hisses produced with the external naries occluded. SVL = snout-vent length in cm; # = number of hisses recorded; frequency values are in hertz, amplitude values in dB, and duration in seconds. All values given are in the format of mean (standard deviation).

Species	SVL	#	Duration	Maximum Amplitude	Minimum Frequency	Dominant Frequency	Maximum Frequency
V. albigularis	30	6	2.67 (0.54)	61.5 (11.3)	1216 (185)	6509 (4690)	11733 (185)
V. albigularis	68	7	6.03 (1.36)	64.0 (16.0)	238 (74)	3582 (541)	18128 (263)
V. gouldii	33	13	0.74 (0.65)	70.8 (5.2)	1005 (552)	4862 (1605)	17158 (1566)

doensis was prominent, and always occurred immediately after the cessation of the hiss (Fig. 6A). The inhalatory sounds have a frequency span which was narrower than that of the hiss, owing to both a decrease in maximum frequency and an increase in minimum frequency (the inhalatory sounds from the larger specimen of *V. albigularis* had a lower minimum frequency, but still had a reduced frequency span). In all cases, the inhalatory sounds have a lower duration and maximum amplitude (compare Table 3 with Table 1). The inhalatory sounds generally lacked a distinct dominant frequency; the dominant frequencies determined using spectral analysis were higher than those of the hiss in four specimens, and lower in the remaining four (Table 3, Figure 6B).

In the two specimens of *Varanus albigularis* inhalatory sounds were recorded with the external naries partly occluded. In this condition the animals made a clearly audible "snuffling" sound. The relative efficacy of nasal occlusion could not be determined, but in both specimens the inhalatory sounds produced with occluded naries showed little change in frequency, an increase in duration, and an increase in maximum amplitude when compared with non-occluded inhalatory sounds.

Mouth opening clicks.- Mouth-opening clicks were the most frequently recorded sounds from those species which include mouth-open gaping as a substantial component of their defensive repertoire (e.g., *Varanus doreanus*, *V. niloticus* and the smaller *V. salvator*). These sounds were produced during the separation of the upper and lower jaws. The mouth-opening clicks were of short duration (less than 0.05 sec.) and typically spanned a frequency range from approximately 400 to 18,000 Hz (Fig. 7). There was no evidence of harmonics within the mouth-opening clicks. All of the mouth-opening clicks were of moderate amplitude- typically around 60-65 dB. By manipulating a recently euthanized specimen of *V. salvator* these sounds were reproduced simply by pulling the lower jaw away from the upper jaw (Fig. 7A).

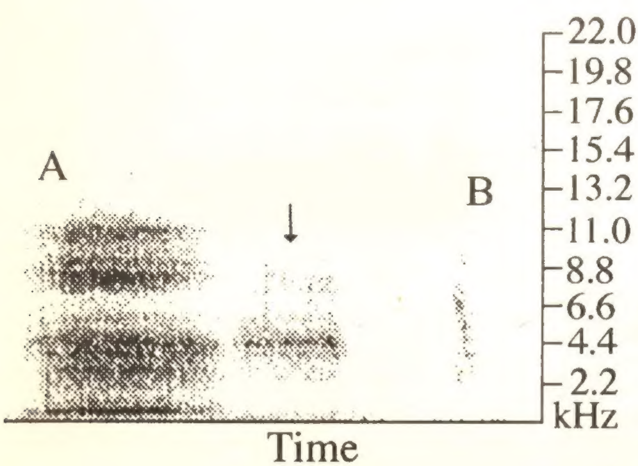

FIGURE 6: Sonograms showing inhalatory sounds from *Varanus*; Y-axis is frequency (in kHz), X-axis is time, and increasing amplitude is denoted by relative darkness. A - a 2.5 second hiss from *V. komodoensis* followed by a 1.3 second inhalatory sound (arrow), note the narrower frequency span of the inhalatory sound; B - a 0.3 second inhalatory sound from *V. doreanus*, note the absence of a distinct dominant frequency.

TABLE 3: Summary statistics for the inhalatory sounds made by *Varanus*. SVL = snout-vent length in cm; # = number of hisses recorded; frequency values are in hertz, amplitude values in dB, and duration in seconds. All values given are in the format of mean (standard deviation).

Species	SVL	#	Duration	Maximum Amplitude	Minimum Frequency	Dominant Frequency	Maximum Frequency
V. acanthurus	18	2	0.64 (0.62)	54.4 (0.6)	1575 (106)	3300 (636)	9375 (1167)
V. albigularis	30	12	0.32 (0.19)	50.5 (9.1)	2293 (1068)	4323 (776)	5397 (1167)
V. albigularis	68	2	0.61 (0.06)	64.0 (0.3)	100 (0)	3795 (78)	5650 (212)
V. doreanus	29	4	0.12 (0.04)	57.1 (1.7)	1797 (531)	3544 (643)	5950 (173)
V. gouldii	33	2	0.71 (0.15)	62.6 (5.7)	958 (25)	3806 (79)	6133 (81)
V. jobiensis	22	4	0.25 (0.17)	53.2 (3.5)	1500 (457)	4856 (1311)	8391 (2390)
V. komodoensis	75	5	0.72 (0.34)	63.1 (4.0)	1615 (428)	3841 (111)	7436 (215)
V. salvator	73	1	0.79	34.8	1160	4160	6825
V. timorensis	23	2	0.14 (0.01)	65.0 (6.7)	788 (159)	3713 (1)	11703 (217)

Laryngeal clicks.- These sounds were only recorded from species which produce relatively high amplitude, long duration hisses (e.g., *Varanus albigularis, V. gouldii* and *V. salvator*). Laryngeal clicks were always produced within 0.1 sec of the cessation of a hiss. These sounds were of short duration (less than 0.02 sec) and had a typical frequency range from 2-12 kHz (Fig. 8). Laryngeal clicks in these species had maximum amplitudes of approximately 60 dB.

DISCUSSION

The hisses and inhalatory sounds examined were all produced with the monitor's mouth closed. Occluding the external naries, even partially, resulted in distinct changes in the acoustic profile of both the hiss and the inhalatory sounds. We take this as strong evidence that these sounds are being produced while the exhalent airstream is flowing predominantly, if not exclusively, through the nasal passageway.

Previous examinations of the larynx of *Varanus* have noted the lack of any internal septa (e.g., Göppert, 1899, 1937; Bels et al., 1995). The paucity of frequency modulation in the hisses examined indicates that these lizards are not altering the diameter of the glottal opening during the hiss. As such, the acoustic profile of the hiss as it exits the glottal opening is determined primarily by the volume of air expelled and the length and diameter of the trachea, factors which are likely to scale with body size. The exhalent

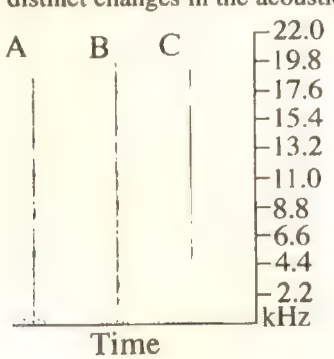

FIGURE 7: Sonograms showing mouth-opening clicks from *Varanus*; Y-axis is frequency (in kHz), X-axis is time, and increasing amplitude is denoted by relative darkness. All of these clicks are of short duration (0.05 sec) and have a broad frequency span. A - click produced by manipulating a euthanized *V. salvator*; B - *V. niloticus*; C - *V. indicus*.

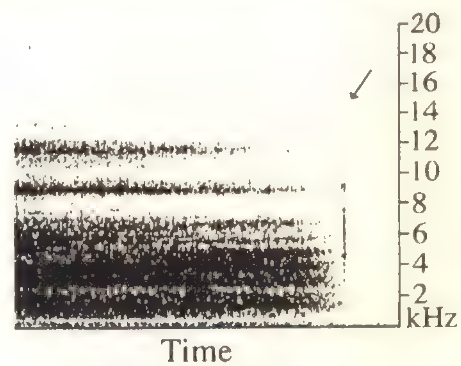

FIGURE 8: Sonograms showing the terminal portion of a hiss of *Varanus albigularis*; Y-axis is frequency (in kHz), X-axis is time, and increasing amplitude is denoted by relative darkness. Note the presence of the short (0.05 sec) laryngeal click (arrow) immediately following the hiss.

airstream flows through the glottis and into the buccal cavity. Frequently during periods of sound production the buccal cavity is expanded to produce the throat display (Bels et al., 1995); this expansion would produce an acoustic filter, with the properties of the filter depending on the relative size of the buccal cavity.

As the exhalent airstream flows through the nasal passageway it will flow perpendicular to the openings of the lateral recess and the cavum nasi proprium- both of these spaces could act as resonance chambers enhancing certain frequencies in the sound (Fig. 1). Near the caudal end of the vestibulum the diameter of the airway can be regulated, at least to a degree, by relative perfusion of the lining vascular sinus. Terminally, the exhalent airstream passes through the external naries, the specific shape of which (Fig. 1) would place a final acoustic signature on the hiss.

These numerous anatomical influences, or at least potential influences, on sound production may account for the broad frequency range of the hiss as well as the presence of multiple high amplitude frequencies which lack a harmonic relationship. These same anatomical influences may explain the acoustic differences observed between the species. Previous studies of the nasal passageway of *Varanus* (e.g., Malan, 1946; Pratt, 1948; Bellairs, 1949, Parsons, 1970) have emphasized the interspecific morphological variation in this region. The position and shape of the external naries is frequently used as a species-level taxonomic character for *Varanus* (e.g., De Lisle, 1996). These morphological variations, coupled with differences in the degree of throat display and body size, could produce the type of acoustic differences we observed among the species examined. Recent studies have suggested that differences in the relative size and structural features of the ophidian nasal passageway may produce acoustically distinct defensive sounds (Kinney et al., 1998; Young and Lalor, 1998). The current study was limited by the general lack of defensive behaviors in long term captive monitors, and the unavailability and expense associated with most species of wild-caught monitors. Further studies are required to document the extent and functional bases of interspecific acoustic variation.

Variations in the frequency profiles of the hiss were observed in every species. A portion of this variation can be attributed to the presence within the hiss of multiple frequency bands of equal amplitude. The significant relationship between amplitude and the acoustic profile of the hiss in *Varanus salvator* suggests that some of this frequency variation may be due to variation in amplitude. The nasal passageway, with the exception of vasodilatation of one portion of the vestibulum, is anatomically static and thus unlikely to produce this type of variation. We hypothesize that some of the acoustic variation may be due to changes in the expansion of the buccal chamber during the throat display.

A previous study of the throat display in *Varanus griseus* (Bels et al., 1995) reported sound production during two different types of buccal movement, one in which air moves through the nasal passageway and the other where the air is circulated only within the buccal cavity. This second type of movement, termed the bucco-pharyngeal breathing pump (Bels et al., 1995) involves rapid fluctuation in the size of the buccal cavity and would likely produce a harmonic signature in the hiss. With the possible exception of the period of frequency modulation and harmonics observed at the onset of the hiss of *V. gouldii* (Fig. 4A), no evidence of two different acoustic signatures was found in the hisses of the species we examined. A detailed comparison of sound production in *V. griseus* and *V. gouldii* could clarify the acoustical influences of the buccal cavity and throat expansion.

The hisses examined from varanid lizards are comparable to those described from snakes (Young, 1991). While the monitors exhibited greater amplitude modulation, neither group exhibits much frequency modulation. The maximum amplitudes we obtained from *Varanus* (Table 1) are within the range previously reported for hissing and rattling in snakes (Young, 1997a). In both groups the hiss spans a broad frequency range, although the maximum frequency recorded from *Varanus* is greater than that seen in the "typical" snake hiss (Young, 1991).

Young (1997a) has argued that the apparent absence of intraspecific acoustic communication

in snakes may be due, in part at least, to the low information content of the sounds they produce. While monitor lizards, like snakes, frequently make noise, there is no evidence of intraspecific acoustic communication among monitors. Varanids can be easily trained to respond to whistle or voice commands: Lederer (1942) and Pfeffer (1959) recount monitors trained to respond to human voices, a claim that has been repeated by Auffenberg (1981). Through the courtesy of Micheal Davenport and Charles Kutris at the National Zoo, we observed the effectiveness of their whistle training of *Varanus komodoensis*; in addition, we have successfully whistle trained (in less than 15 repetitions) a specimen of *V. exanthematicus*. Many species of monitor live in social groups, which normally have a distinct dominance hierarchy headed by the largest males (Auffenberg, 1981; Daltry, 1991; Lenz, 1995). While aggressive acts are common within these social groups, these are normally not associated with sound production. As Daltry (1991) has noted, sound is not a significant part of the social structure of monitor lizards. Auffenberg (1981) provided a detailed discussion of the relative scarcity of behavioral responses to acoustic stimuli in wild *V. komodoensis*. Rebutting those workers who have claimed monitors are deaf, Auffenberg (1981: 141) noted that the lack of behavioral response to sound is not an, "indication of their ability to do so, but rather of their disinterest." The lack of acoustic specialization which characterized all the varanid defensive sounds we examined- and which is also typical of the defensive sounds of snakes (Young, 1991, 1997a; Young and Brown, 1995)- results in sounds which have low information content and which may be of little "interest" to conspecific monitors.

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THE COBRAS OF THE GENUS *NAJA* IN INDIA

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(with one text-figure)

ABSTRACT.- The species of cobra inhabiting India are reviewed. All Asiatic cobras used to be considered part of a single species, *Naja naja*. In fact, four species are found in India alone: *Naja naja* (more or less throughout the country), *Naja kaouthia* (east and north-east), *Naja oxiana* (extreme north-west) and *Naja sagittifera* (the Andaman Islands). The systematics of the four species is reviewed, and all four species are described, and the literature on their natural history and medical importance summarised.

KEY WORDS.- *Naja*, Serpentes, taxonomy, morphology, India.

INTRODUCTION

In the minds of people all over the world, one of the animals that most symbolises India is the cobra, and in particular the image of a cobra rearing out of a basket and "dancing" to the sound of a snake charmer's music. As far as popular awareness is concerned, cobras are by far the best known snakes of India. However, many aspects of their natural history and biology remain poorly known. Even the most basic of all categories of biological knowledge, namely the taxonomy of these animals, has remained largely unstudied until recently.

In this paper, I will summarise recent taxonomic developments concerning the species of *Naja* occurring in India, provide descriptions of the species as currently recognised, and provide guidelines for the identification of cobra specimens from areas where more than one species occurs, a matter which has caused considerable problems in the past. I will also attempt to provide updates on other literature on these animals, especially concerning snakebite and similar topics.

SYSTEMATICS OF THE GENUS

Systematic history.- Few groups of venomous snakes have as confused a taxonomic history as the Asiatic cobras. The extreme variability of these snakes, especially in their colour pattern, has obscured the affinities of many populations for decades. Since the latter part of the 19th century, all Asiatic cobra populations have generally been lumped into one single species, *Naja naja* (referred to as *Naja* (or sometimes *Naia*) *tripudians* in much of the 19th century literature). Over the whole of Asia, 10 subspecies were recognised (e.g., Klemmer, 1963; Leviton, 1968; Harding and Welch, 1980; Golay, 1985; Welch, 1988). Of these, four were listed for India: *Naja naja naja* (spectacled or binocellate cobra), reported to occur throughout India, as well as in Pakistan, Sri Lanka, and Bangladesh; *N. n. kaouthia* (monocellate or monocled cobra), reported from north-eastern India (Gangetic Plain, Orissa, Bengal, Assam) as well as from Bangladesh, and on to Malaysia, southern Vietnam and south-western China); *N. n. oxiana* (Central Asian cobra), reported from Kashmir, and sometimes other parts of north-western India; and *N. n. sagittifera* (Andaman cobra), from the Andaman Islands. This classification has been followed fairly consistently in the literature, even though a number of authors, such as Taylor (1965), Leviton (1968), Saint Girons (1972) and Golay (1985) have remarked on the problems posed by the systematics of this group.

The only major revision of the group this century was carried out by Deraniyagala (1945, 1960, 1961), who split the complex into four species, of which three (*Naja naja*, *N. kaouthia*, and *N. oxiana*) were listed for India, with Indian distributions corresponding to those listed for the subspecies above. Furthermore, Deraniyagala described several subspecies of *N. naja* from India, these being *N. n. indusi* (Punjab and neighbouring areas), *N. n. madrasiensis* (southern India), *N. n. gangetica* (north-eastern India), *N. n.*

bombaya (Maharashtra and neighbouring areas) and *N. n. karachiensis* (southern Pakistan and adjoining parts of India). Deraniyagala considered the nominate form, *N. n. naja*, to be restricted to Sri Lanka. However, the evidence for Deraniyagala's revisions was often rather weak, and his papers have been largely ignored by later workers.

Recent taxonomic developments.- Because of the tremendous variation in colour pattern and other characters displayed by these snakes, any attempt to understand their taxonomy has to be based on the simultaneous analysis of a number of different characters and character systems, and on the use of a large number of specimens. Molecular methods such as comparative mitochondrial DNA sequencing can further resolve problems caused by variation in morphological characters. The taxonomy of the Asiatic cobra complex has now been extensively revised using these methods. The analyses resulted in the splitting of what was considered *Naja naja* into 10 species (Wüster, 1990; 1992a,b; Wüster and Thorpe, 1987; 1989; 1990; 1991; 1992a; 1992b; 1994; Wüster et al., 1995, 1997; reviewed in Wüster, 1996).

Of these 10 species, four are definitely known to occur in India and neighbouring areas: the spectacled cobra (*Naja naja*) is found throughout India, with the exception of Assam and some of the northern mountains; the monocellate cobra (*N. kaouthia*) is found in the Gangetic Plain, Bengal, and north-eastern India; the Central Asian cobra (*N. oxiana*) is found in northern India (Kashmir, Himachal Pradesh); and the Andaman cobra (*N. sagittifera*) is restricted to the Andaman Islands. *Naja naja* and *N. oxiana* occur sympatrically in parts of north-western India and Pakistan, and *N. naja* and *N. kaouthia* do so in parts of north-eastern India (Wüster and Thorpe, 1991; 1992a).

In addition to these four species, Wüster and Thorpe (1992a; 1992b) noted two specimens from Bihar state, northern India, which could not be classified as any of the known species of Asiatic *Naja*. They may represent hybrids, aberrant specimens, a locally differentiated population of *N. naja*, or it is possible that another, as yet undescribed, species is present in north-eastern India. More material will be required to resolve this problem.

Significance of recent taxonomic developments.- The splitting of the formerly single species *Naja naja* has a number of implications for research on other aspects of these animals. For instance, many reports on the natural history of Asiatic cobras cannot be linked to any particular species, which is of some relevance in view of reported differences in such elementary natural history traits as mating season (e.g., Lingenhöle and Trutnau, 1989).

The recent taxonomic discoveries are of particular relevance for research on the venoms of these snakes and the treatment of their bites. The bites of different cobra species have been shown to produce symptoms which differ very considerable, ranging from almost entirely neurotoxic (e.g., *Naja philippinensis* - Watt et al., 1986, 1988, 1989) to principally necrotic in some *N. kaouthia* and/or *N. sumatrana* populations (Reid, 1964), suggesting extensive variation in venom composition.

However, because of the hitherto incomplete understanding of the systematics of this group, the vast literature on the venoms and bites by these snakes is often taxonomically uninterpretable. The problem extends to some clinical series of bites containing a mixture of victims bitten by different species (e.g., Reid, 1964), and to specimen descriptions so vague that it is impossible to be certain which species were involved. In India, this is particularly the case with cobras lacking a hood mark, which are frequently described as *Naja oxiana* when they are in fact patternless *N. naja*. This leads to difficulty in interpreting some of the literature, to the extent that the vast majority of experimental venoms discussed in the toxinological literature cannot confidently be ascribed to any one single species of Naja (Wüster and McCarthy, 1996).

This confusion in the literature is particularly regrettable because of the potentially devastating effect this can have on the formulation of treatment strategies for human patients bitten by venomous snakes. The venoms of different cobra species can have quite different immunological properties, which can lead to an antivenom against one species being ineffective against the

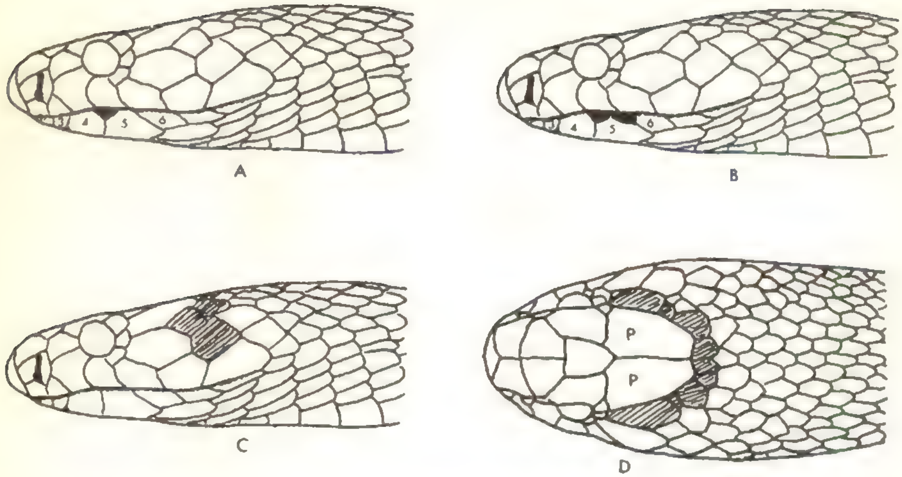

FIGURE 1: Head scalation in Asiatic *Naja*. (Diagrams modified from Bogert, 1943). A. Specimen with one cuneate scale (shaded) between the 4th and 5th infralabials. Typical arrangement in *Naja naja*. B. Specimen with two cuneate scales (shaded), between the 4th and 5th, and the 5th and 6th infralabials. Note that in this arrangement, the 5th infralabial is excluded form the edge of the mouth. Frequent arrangement in *Naja kaouthia*. C. Posterior temporal scales. In this study, posterior temporals (shaded) were defined as all scales other than parietals and supralabials contacting the posterior part of the anterior temporals. D. The nuchals (shaded) are defined in this study as all scales other than postoculars which contact the anterior and lateral edges of the parietal scales.

venom of another (Vogtman, 1950; Warrell, 1986; Viravan et al., 1992). Clearly, a full understanding of the population systematics of these snakes is essential for coherent research into venom effects and antivenom effectiveness, and for the optimization of antivenom efficacy.

THE COBRA SPECIES OF INDIA

Notes on the species descriptions.- Some of the scalation characters used in the descriptions of the various *Naja* species were taken from a previous study of the genus (Wüster, 1990), and are therefore likely to be unfamiliar to many readers:

- The cuneates are small, triangular scales inserted between the 4th and 5th and/or 5th and 6th infralabial scales (Fig. 1A, B). These are diagnostic for the genus, and their number can help distinguish some of the Asiatic *Naja* species, especially *N. kaouthia*.

- Posterior temporals were defined as scales which contact the posterior edge of the anterior temporals (Fig. 1C); other larger shields not in contact with the anterior temporals are excluded. In the scalation tables for each species, the sum for of both sides of the head is given.

- Nuchals are here defined as scales other than the postoculars which contact the lateral and posterior edges of the parietal scales (Fig. 1D)

- Dorsal scale rows are counted in a straight line across the body. In order to determine where dorsal scale rows should be counted, the ventrals were numbered from the head, and counts were taken at specific positions of the total count. For instance, in a specimen with 200 ventral scales, the dorsals at 20% ventral count were recorded at the level of the 40th ventral (20% of the total count), the dorsals at 40% ventral count at the level of the 80th ventral, etc. This is more precise than simple mid-body counts, and since these are the data available from previous studies of the genus, they comprise the most comprehensive database so far of scalation variation in these species.

- Dentition: counts were made by removing gum tissue from each of the jaw bones on one side of each specimen, and counting the number of tooth sockets. It is important to count sockets rather than teeth, because teeth may be missing from some sockets, and this would artificially introduce variance into the sample. The pres-

ence/absence of a solid maxillary tooth is practically impossible to determine without some dissection of gum tissue behind the fang.

NAJA NAJA (LINNAEUS, 1758) - THE INDIAN SPECTACLED COBRA

Coluber naja Linnaeus, 1758. Type locality: in India orientali, restricted to Sri Lanka by Deraniyagala, 1945).

Naja tripudians Merrem, 1820.

Naia tripudians forma typica Boulenger, 1896.

Naia tripudians var. *caeca* Boulenger, 1896 (part.)

Naja naja Anderson, 1899.

Naja naja naja Stejneger, 1907.

Naia naia col. var. *polyocellata* Deraniyagala, 1939.

Naja naja gangetica Deraniyagala, 1945.

Naja naja madrasiensis Deraniyagala, 1945.

Naja naja indusi Deraniyagala, 1960.

Naja naja bombaya Deraniyagala, 1961.

Naja naja karachiensis Deraniyagala, 1961.

Naja naja polyocellata Mahendra, 1984.

Distribution.- Pakistan (except probably most of Baluchistan, parts of the North-West Frontier Province, and desert areas elsewhere - Minton, 1966; Joger, 1984; Khan, 1990), India (throughout, except probably Assam, some areas of Kashmir, high areas above 2,000 m, and extreme deserts), Sri Lanka, southern Nepal and Bangladesh. Mahendra (1984) reports its presence in Bhutan, without further details. The most easterly record appears to be from Tangail District, Bangladesh, and the most westerly record is from Duki, Baluchistan (Wüster and Thorpe, 1992a). As it has been recorded from Drosh, in the Chitral Valley (Wüster and Thorpe, 1992a), it may also occur in the Kabul River Valley in extreme eastern Afghanistan.

DESCRIPTION

Size.- Most adults measure 100-150 cm. Occasional specimens of approximately 210-220 cm have been recorded, especially in Sri Lanka. Hatchlings usually measure 25-30 cm.

Colour pattern.- The Indian spectacled cobra is a very variable snake in terms of colour and pattern. The ground colour can be grey, yellowish, tan, brown, reddish or black. Some specimens have a dorsal colour pattern as well as a hood mark. The most frequently visible pattern feature is a posteriorly convex light band at the level of the 20th to 25th ventral. This often continues across the ventral side, where it forms the light band between the first and second dark bands. Many specimens, especially adults, also exhibit some salt-and-pepper speckling on the dorsal scales. Some specimens, especially those from Sri Lanka, have a series of often ill-defined, ragged bands along the dorsum. Ontogenetic colour change is common in the north-western populations, especially those from southern Pakistan and north-western India. In southern Pakistan, young specimens tend to be grey (after preservation), with or without a hood mark. Adult specimens are normally uniformly black above, although most of the ventral surface, excluding the throat, remains light.

The throat and ventral pattern in this species is also quite variable. In most specimens, there is a light throat area followed by one or several dark bands 4-7 ventral scales wide. In adult specimens, there is often a considerable amount of mottling on the throat and on the venter, so that the pattern is much less clear in this species than in some others, such as *Naja kaouthia*. There is usually one pair of lateral spots on the throat at the junction of the ventral and dorsal scales. Except in specimens from the north-west, these spots extend onto the second dorsal scale row. Their position varies, being more anterior in specimens from the north-west and more posterior in specimens from other areas (anterior edge at level of 7th to 12th ventral). In populations with melanistic adults, e.g., in southern Pakistan, the throat pattern is usually obscured by dark pigment.

Naja naja sometimes lacks a clear border between the light throat area and the darker side of the neck, and there is often no dark line separating the two. The first dark ventral band, which forms the posterior end of the light throat area, is very variable in position: the first ventral involved varies from the 10th to the 21st.

Specimens from Sri Lanka are notable for having a large number of dark bands (sometimes up to 20) across the venter. Specimens from other

areas only have 1-4 dark bands. Specimens from many areas may have a strongly mottled or speckled venter. In adult melanistic specimens from the north-western part of the range, the dark dorsal colour encroaches onto the outer fifth on each side of the ventrals, leaving the middle three-fifths light.

Hood mark.- The best known feature of the colour pattern of the Indian binocellate cobra is the spectacled hood mark. When present, this consists of two light ocelli with dark centres, whose posterior edges are linked by a posteriorly-convex light arc. The dark spot inside the ocelli nearly always has a diameter of at least 2 dorsal scale rows (usually less in other species with a spectacle marking). There is usually a conspicuous black border to the hood mark, which may be interrupted in places. The anterior edge of the hood mark is at the level of the 7th - 12th ventral scale, the posterior edge at the level of the 14th-21st ventral scale. The hood mark of the Indian cobra is never linked to the light colour of the throat. However, it is particularly important to note that the hood mark of *N. naja* is frequently absent, and that the presence or absence of this hood mark is not an adequate character for the distinction of this species from any other cobra species.

Scalation.- The scalation of *Naja naja* is very variable, and shows strong geographic variation. Specimens from the north-west of the range have low dorsal scale row counts, whereas specimens from other areas have the highest dorsal scale row counts of any Asiatic cobra species. More details are given in the paragraphs on geographic variation in this species. Table 1 summarises the variation in selected scalation characters in this species.

Dentition.- The longest fang recorded in this study measured 7.33 mm from the distal end of the basal orifice to the tip, and was measured in a male specimen from Bangladesh measuring 1627 mm in total length. The fangs of this species are the longest in relation to head and body size of any of the Asiatic *Naja*. The fangs of this species are not adapted for spitting. Dentition counts are tabulated in Table 2.

DIAGNOSIS

The Indian spectacled cobra is sympatric with two other cobra species: the Central Asian cobra, *Naja oxiana*, occurs sympatrically in the northern half of Pakistan and probably extreme northern India, and the monocellate cobra, *N. kaouthia*, occurs sympatrically in northern India (from Delhi eastward).

The characters that allow *N. naja* to be distinguished from *N. oxiana* in the zone of sympatry are shown in Table 3, and those used to discriminate between *N. naja* and *N. kaouthia* are listed in Table 4.

The distinction between *Naja naja* and *N. oxiana* has often proved problematic, many authors assigning all specimens without a hood

TABLE 1: Scalation of *Naja naja*. Note that there is considerable geographic variation in many scalation characters, and the whole range is unlikely to be encountered in any particular locality.

	Males		Females	
	Range	Mean ± S.D.	Range	Mean ± S.D.
Ventrals	171 - 197	187.02 ± 4.61	178 - 196	188.90 ± 3.87
Subcaudals	53 - 67	60.09 ± 3.13	50 - 65	57.96 ± 3.21
Cuneates	0 - 4	2.32 ± 0.85	0 - 4	2.36 ± 1.06
Posterior temporals	6 - 10	7.45 ± 1.00	5 - 9	7.18 ± 0.85
Nuchals	5 - 13	8.09 ± 1.31	5 - 10	7.61 ± 1.11
Dorsal rows at 10th ventral	23 - 37	30.19 ± 3.56	23 - 37	30.00 ± 3.64
Dorsals at 20% ventral count	19 - 25	22.12 ± 1.19	19 - 25	21.97 ± 1.37
Dorsals at 40% ventral count	21 - 25	22.38 ± 1.02	20 - 25	22.28 ± 1.30
Dorsals at 60% ventral count	19 - 23	20.71 ± 1.19	17 - 24	20.46 ± 1.65
Dorsals at 80% ventral count	13 - 18	15.36 ± 0.88	15 - 17	15.51 ± 0.85
Dorsals at vent	15 - 18	16.01 ± 1.00	15 - 18	16.23 ± 0.96

TABLE 2: Dentition of *Naja naja*. Maxillary tooth number is variable, specimens from Pakistan and north-western India usually having 0, specimens from elsewhere 1.

	Males		Females	
	Range	Mean ± S.D.	Range	Mean ± S.D.
Palatine teeth	6-9	6.98 ± 0.51	6-8	6.90 ± 0.39
Pterygoid teeth	12-21	16.88 ± 1.71	13-20	16.71 ± 1.73
Dentary teeth	13-17	14.08 ± 0.56	12-15	13.90 ± 0.55
Solid maxillary teeth	0-1	0.55 ± 0.49	0-1	0.59 ± 0.49

TABLE 3: Distinguishing characters of *Naja naja* and *N. oxiana* in their zone of sympatry in north-western India and Pakistan. Specimens from other parts of the ranges of the two species are easier to distinguish due to additional scalation differences (lack of a cuneate in northern *N. oxiana* populations; 29 or more scale rows around the hood in southern and eastern *N. naja* populations, versus 23-27 in *N. oxiana*). M = males; F = females.

	Naja naja	*Naja oxiana*
Ventral scales	M 184 - 193; F 182 - 196	M 199 - 207; F 191 - 210
Subcaudal scales	M 58 - 67; F 53 - 63	M 66 - 71; F 62 - 70
Solid maxillary teeth	0 (very rarely 1)	1
Juvenile pattern	Speckled or uniform, one or two ventral bands, often hood mark and lateral throat spots	Conspicuously banded, both ventrally and dorsally, along most of body length, no hood mark or lateral throat spots

TABLE 4: Distinguishing characters of *Naja naja* and *N. kaouthia* in northern and north-eastern India. Specimens from other parts of the ranges of the two species may differ with respect to the characters listed.

	Naja naja	*Naja kaouthia*
Hood mark	Spectacle-shaped or absent	Monocellate or mask-shaped, never totally absent
Scale rows at level of 10th ventral	Usually > 29	Usually 29 or fewer
Scale rows at 40% of the ventral scale count	Usually 23	Usually 21
Throat pattern	Often indistinct, lateral spots usually encroach on second dorsal scale row	Usually distinct, lateral spots usually encroach on lowest dorsal scale row only

mark to *N. oxiana*. In particular, it should be noted that the black cobras found in parts of north-western India, Pakistan, south-western Nepal and some other areas are not *N. oxiana*, which is normally some shade of brown, but, to my knowledge, never black.

Distinguishing *Naja kaouthia* and *N. sagittifera* from *N. naja* is usually straightforward due to the difference in hood mark shape and throat pattern, and, in the case of the latter, geographic distribution.

GEOGRAPHIC VARIATION

As mentioned in the description, *Naja naja* exhibits extensive geographic variation in colour pattern and scalation. This pattern variation has led to considerable confusion regarding the affinities of some populations. Specimens without hood marks have been routinely assigned to *N. oxiana* or equivalent taxa by some workers, and other workers have encountered difficulties in interpreting pattern variation in some regions, such as Pakistan (Minton, 1966; Joger, 1984).

The great geographic variation displayed by this species has led to a number of subspecies being described, principally by Deraniyagala (1945; 1960; 1961). These subspecies were all synonymised with *Naja naja* by Wüster and Thorpe (1992a). The reasons for this are summarised in the following paragraphs. For more details and a multivariate analysis of geographic

variation in *N. naja*, see Wüster and Thorpe (1992a).

Deraniyagala (1945) restricted the type locality of *Naja naja* to Sri Lanka, calling the populations of that island *N. n. naja*. He had previously (Deraniyagala, 1939) referred to some Sri Lankan specimens, with further hood markings other than the spectacle, as *Naia naia* col. var. *polyocellata*, but considered this a colour variety rather than a subspecies. However, the name *polyocellata* has subsequently been used as a subspecific name for *N. naja* specimens from Sri Lanka (e.g., Mahendra, 1984). Since Sri Lanka has also been selected as the restricted type locality of *N. naja*, and there has been no suggestion that "*Naja naja polyocellata*" represents a geographically separated population found on the same island, this is clearly self-contradicting.

Deraniyagala (1945) regarded the populations from southern India as different because they have a lower number of dark ventral bands (1-3) than the Sri Lankan specimens (up to 15 or more). He also stated, citing Bogert (1943), that Sri Lankan cobras have fangs adapted for spitting, whereas those from southern India lack this adaptation. On this basis, the southern Indian populations were described as a new subspecies, *Naja n. madrasiensis*. In fact, the Sri Lankan cobras, like all *N. naja* populations, have non-spitting fangs (Wüster and Thorpe, 1992b). Sri Lankan specimens do tend to have a higher number of dark ventral bands than Indian specimens, but there is in fact no major differentiation in the overall phenotype which might warrant the recognition of these forms as taxonomically distinct.

The cobras of north-western India and Pakistan, which Deraniyagala (1960) described as *Naja n. indusi*, were considered distinct from the southern and eastern populations primarily on the basis of the absence of a solid maxillary tooth, as noted by Bogert (1943). Unfortunately, Bogert examined only relatively small samples from northern India and Pakistan. In fact, the number of solid maxillary teeth is variable even within populations of *N. naja*; there are occasional specimens from Pakistan with solid maxillary teeth, and in other parts of India, occasional specimens lack solid maxillary teeth. There is no other indication of phenotypic differentiation between specimens with and without solid maxillary teeth, so that this character cannot be regarded as being of taxonomic importance. The main differences between north-western populations of this species and those from the remainder of the range concern the scalation: the north-western populations have fewer dorsal scale rows around the hood (25-29) and at mid-body (19-21) than those from other regions (29-37 and 23-25, respectively). The pattern of differentiation in the scalation between the north-western and the other populations appears to be clinal rather than categorical, as populations from Maharashtra and Madhya Pradesh are intermediate between the north-western populations and the others. Consequently, the north-western populations should not be recognized as a separate subspecies.

Deraniyagala (1945) also recognized the populations from the Gangetic Plain as a separate subspecies, *Naja n. gangetica*. In his original description, this subspecies was never properly diagnosed from other Indian populations. The populations from the Gangetic Plain are not in any way strongly differentiated from other populations of this species.

Naja naja karachiensis Deraniyagala, 1961 was described on the basis of most adult specimens being black dorsally, without any sign of a hood mark. The young specimens that we have examined often had a spectacled hood mark. The black colour of the adult specimens is an ontogenetic change, superimposed upon the basic colour pattern. Otherwise, these populations are not consistently distinct from other Pakistani/north-west Indian spectacled populations, and therefore do not warrant subspecific recognition.

Finally, Deraniyagala (1961) described the Maharashtra populations as *Naja n. bombaya*, primarily on the basis of the combination of a lack of solid maxillary teeth and cuneate scales. Only a single specimen was examined by that author. Deraniyagala's reasons for conferring subspecific status on these populations are misleading: all the specimens from Maharashtra that I have examined have at least one cuneate on each side, and 6 out of 10 had a solid maxillary tooth. Cuneate scales can occasionally be absent in any of the Asiatic *Naja* species, so that their

absence in one specimen cannot be used to infer a separate taxonomic status. In any case, the description of a new subspecies on the basis of a single specimen is ill-considered, as it ignores the extent of variation within the proposed subspecies.

In conclusion, the subspecies of *Naja naja* erected by Deraniyagala are all invalid, either because the character differences used to define them are insignificant when related to the pattern of variation in the overall phenotype, or because the data on which the description was based were insufficient, or simply wrong. There is no disputing that *N. naja* exhibits considerable geographic variation in many character systems, and that this deserves in-depth study once sufficient material is available. However, the pattern is clearly a complex one, and the description of subspecies on the basis of a few arbitrarily selected characters will do nothing to enhance our understanding of this problem.

NATURAL HISTORY

Much of the published information on the natural history of Asiatic cobras is difficult to interpret due to the past confusion regarding the systematics of these animals. Many authors dealing with the natural history of Asiatic cobras simply referred to them as *Naja naja*, and, in many cases, it is impossible to determine which of the 10 species of the genus now recognised was being referred to. Other authors lumped their experiences of different species into one set of observations on "*Naja naja*", and again, it is often impossible to determine which piece of information refers to which species. For instance, in the case of information provided by Smith (1943) and Wall (1913a, 1921), it is probable that at least some of the information is based on *N. kaouthia*, but it is unfortunately not possible to determine the effect of this.

Habitat.- The spectacled cobra is highly adaptable, and can be found in a variety of habitats, including agricultural areas (particularly rice-growing areas) and even in and around villages and cities. Holes in the dams of rice fields and termite mounds are favourite haunts. It is reported to be more common in open areas than in jungles. In Pakistan, it has been reported to favour damp grasslands (Minton, 1966).

Reproduction.- Twelve to 30 eggs are laid between April and July, probably depending on location (Wall, 1913a; Whitaker, 1978). The female is reported to stay with her eggs until they hatch after about 2 months. Communal nesting is known to occur. In captive hybrids of *Naja naja* and *N. kaouthia*, apparent cooperation in brood care between male and female has been observed (Campbell and Quinn, 1975).

Food.- Adults are reported to eat mostly rats, as well as amphibians and other vertebrates, such as lizards (even monitors have been reported as prey - Wall, 1913a) and snakes, including venomous species such as *Echis carinatus* (Minton, 1966). Eggs are also taken, and cobras will raid chicken coops and eat both eggs and chicks. Juveniles feed mostly on amphibians, as well as other snakes (Whitaker, 1978) and lizards in drier areas.

Behaviour.- Diurnal and crepuscular, but has also been observed active at night. This species is shy, and always attempts to escape if it feels threatened. If cornered, it spreads a hood, raises up to the first third of its total length, and may face the adversary, producing a loud, hollow-sounding, explosive hiss. It generally bites only as a last resort, and many specimens just strike with their mouths closed, "headbutting" their opponent. Many bites result only in minimal symptoms, presumably because little or no venom is injected. Young specimens are reported to be more emphatic in their self-defence than adults. The fangs of this species are not adapted for spitting. Reports of spitting are probably due to confusion with other species.

MEDICAL IMPORTANCE

Naja naja is the most widespread cobra in India and neighbouring countries, and is thought to be an important cause of snakebite in much of its range. Statistics from India are lacking, although it is usually thought to be the most important venomous snake there (e.g., Swaroop and Grab, 1954; Murthy, 1990). In Sri Lanka, it is one of the three species causing the highest snakebite mortality (Sawai et al., 1984; de Silva, 1976,

1981; de Silva and Ranasinghe, 1983). Bites by Sri Lankan specimens have been reported to cause both neurotoxicity and necrosis (Theakston et al., 1989; de Silva, 1990a,b; Warrell, 1995). Detailed studies appear to be lacking from India, but Wall (1913a,b, 1921) also reported a combination of neurotoxicity and local symptoms. In view of the vast geographic range of *N. naja*, a study of venom variation in this species would be of great importance.

Neostigmine and other acetylcholinesterase drugs have been shown to reverse respiratory paralysis caused by the venom of this and other cobra species (Banerjee et al., 1972; Pandey et al., 1979; Sharan, 1982; Watt et al., 1986, 1989), and should be tried on cobra bite victims with neurotoxic symptoms (Warrell, 1990, 1995).

NAJA OXIANA (EICHWALD 1831) - THE CENTRAL ASIAN COBRA

Tomyris oxiana Eichwald, 1831.
Naja tripudians var. *caeca* Boulenger, 1896.
Naja naja oxiana Stejneger, 1907.
Naja oxiana Bogert, 1943.

DISTRIBUTION

Well known from Turkmenia, Uzbekistan, Tadzhikistan, north-eastern Iran, south-eastern and northern Afghanistan, and northern Pakistan (North-West Frontier Province and northern Baluchistan). There are more recent records from several parts of the Pakistani Punjab (Khan, 1977, 1983, 1984, 1986, 1990). In India, Murthy and Sharma (1976) and Murthy, Sharma and Sharma (1979) reported specimens from the Punch Valley, north-west of Jammu, and Mahajan and Agrawal (1976) described a specimen from the Simla Hills, in Himachal Pradesh. Reports from Rajahstan and Gujarat (e.g., Biswas and Sanyal, 1977; Murthy, 1990; Sundersingh, 1960) and other parts of north-western India are probably based on specimens of *Naja naja* which lacked a hood mark. The range of *N. oxiana* is split into two parts by the Hindukush mountains and the deserts of southern Afghanistan, south-eastern Iran and south-western Pakistan (Joger, 1984).

DESCRIPTION

Size.- Most adults measure between 110 and 140 cm in overall length. Specimens longer than 150 cm are rare.

Colour pattern.- The Central Asian cobra exhibits considerable ontogenetic variation in its pattern. Young specimens are strongly banded, both dorsally and ventrally. Anteriorly, the dark and light bands are approximately 3-5 ventrals wide, of equal width, and completely encircle the body. Going back along the body, the bands become narrower, and less clear on the ventral side. The ventral banding disappears altogether in the posterior third of the body. Going back, the dorsal light bands split into double bands, which then split into quadruple bands, and so on. The total number of light bands is approximately 45. Despite the presence of very obvious bands, the general appearance of the young specimens is very faded. The banding fades slowly with increasing size, but is still faintly visible, at least in the anterior part of the body, in young adults (up to 90-100 cm SVL).

The dorsum of large adult specimens is more or less uniform, and of various shades of brown, but not normally black. The scales often have lighter edges than centres. The ventral surface is much lighter (cream-coloured after preservation), with some mottling. The first 2-6 dark ventral bands present in young specimens persist. The first two are generally distinct, the more posterior ones less so. The first of these bands occupies a more anterior position (first ventral involved: 4-10) than in other Asiatic cobras. There are no lateral blotches on the throat. The pattern of *Naja oxiana* is not very variable.

Hood mark.- *Naja oxiana* has no distinct hood mark. The banding seen on the dorsum continues onto the neck.

Scalation.- *Naja oxiana* differs from all other Asiatic cobras by its very high ventral and subcaudal scale counts. Only *N. naja*, and, very occasionally, the monocellate cobra, *N. kaouthia*, may overlap in both ventral and subcaudal scale counts. Specimens from the former Soviet Central Asia and Iran do not generally have any cuneate scales, whereas specimens from east of the Hindukush Mountains generally have one on each side. The total variation in the

TABLE 5: Scalation of *Naja oxiana* from throughout the species' range. Cuneates are generally present in specimens form India, Pakistan and eastern Afghanistan, but absent in specimens from Turkmenia, Uzbekistan, Tadzhikistan, Iran and northern Afghanistan.

	Males		Females	
	Range	Mean ± S.D.	Range	Mean ± S.D.
Ventrals	193 - 207	198.11 ± 3.36	191 - 210	201.16 ± 4.88
Subcaudals	63 - 71	68.00 ± 1.95	57 - 70	63.25 ± 2.70
Cuneates	0 - 2	0.5 ± 0.86	0 - 4	0.95 ± 1.39
Posterior temporals	6 - 9	7.81 ± 0.85	6 - 10	7.68 ± 1.06
Nuchals	8 - 12	9.57 ± 1.21	7 - 12	9.89 ± 1.15
Dorsals at 10th ventral	23 - 27	24.88 ± 0.86	23 - 26	24.63 ± 0.76
Dorsals at 20% ventral count	19 - 23	21.00 ± 0.89	19 - 21	20.73 ± 0.65
Dorsals at 40% ventral count	21 - 25	21.46 ± 1.03	21 - 23	21.31 ± 0.67
Dorsals at 60% ventral count	19 - 23	20.69 ± 1.01	19 - 22	20.63 ± 0.83
Dorsals at 80% ventral count	15 - 17	15.54 ± 0.86	15 - 17	16.53 0.70
Dorsals at vent	15-18	16.77 ± 0.82	16-17	16.95 ± 0.23

scale counts of this species is summarised in Table 5.

Dentition.- This species has two peculiarities as far as its dentition is concerned: firstly, there is a tendency in many specimens to have two teeth ankylosed to the same socket, giving the appearance of having two rows of teeth on the palatine, pterygoid and dentary bones; secondly, the venom discharge orifice of the fangs is in a much more lateral position than in other Asiatic cobras, where it tends to face directly forward.

The fangs of this species are not adapted for spitting. The longest fang recorded in this study measured 5.62 mm, and originated from a specimen from the Dushanbe area, Tadzhikistan, which measured 1448 mm in total length. The fangs of this species are relatively shorter than those of *Naja naja* and *N. kaouthia*. Dentition counts are given in Table 6.

DIAGNOSIS

The only cobra species which occurs sympatrically with *Naja oxiana* is the Indian spectacled cobra, *N. naja*. The differences between the two taxa are shown in Table 2. *Naja oxiana* can be distinguished from all other Asiatic cobras on the basis of its high ventral and/or subcaudal scale counts. Specimens of the monocellate cobra (*N. kaouthia*) with exceptionally high ventral and subcaudal scale counts may be distinguished from *N. oxiana* by the possession of a hood mark, a distinct throat pattern with lateral spots, and a higher number of dorsal scale rows at the level of the 10th ventral.

NATURAL HISTORY

Habitat.- This species favours drier areas than the other Indian cobra species, being found mainly in arid or semi-arid areas, and in dry mountain situations, up to about 2000 m in Baluchistan. In Pakistan, it is reported to occur in drier areas than

TABLE 6: Dentition of *Naja oxiana*. Note that contrary to some literature statements, exactly one maxillary tooth is present on each side.

	Males		Females	
	Range	Mean ± S.D.	Range	Mean ± S.D.
Palatine teeth	7 - 10	8.09 ± 0.80	6 - 8	7.29 ± 0.56
Pterygoid teeth	14 - 20	7.52 ± 1.5	15 - 21	17.09 ± 1.55
Dentary teeth	13 - 14	13.69 ± 0.42	12 - 14	13.56 ± 0.55
Maxillary teeth	1	1 ± 0	1	1 ± 0

the sympatric *Naja naja* (Khan, 1977).

Food.- Juveniles eat amphibians and lizards, adults also feed on small mammals.

Behaviour.- Like other cobras, this species is shy and will avoid confrontation if possible. When alarmed or cornered, spreads hood and hisses loudly. *Naja oxiana* does not spit venom.

MEDICAL IMPORTANCE

In India and neighbouring areas, *Naja oxiana* occupies mostly relatively thinly populated regions, and it does not appear to be a very common snake, at least compared to the two other species in other parts of India. No detailed accounts of bites by this species in India or Pakistan have been published to my knowledge.

NAJA KAOUTHIA LESSON 1831 - THE MONOCELLATE COBRA

Naja kaouthia - Lesson in: Ferussac, 1831.

Naja tripudians var. *fasciata* - Boulenger, 1896.

Naja naja naja - Stejneger, 1907.

Naja naja atra - Stejneger, 1907.

Naja tripudians var. *sagittifera* - Wall, 1913a.

Naja tripudians var. *viridis* - Wall, 1913a.

Naja naja sputatrix - Bourret, 1936.

Naja naja kaouthia - Smith, 1943.

Naja kaouthia kaouthia - Deraniyagala, 1960.

Naja naja leucodira (non-Boulenger 1896) - Reid, 1964.

DISTRIBUTION

Northern and eastern India (Gangetic Plain, Bengal, Orissa, Sikkim, Assam; most westerly record is Sonipat, Haryana - Wüster and Thorpe, 1992a; most southerly record is from Orissa - Murthy and Acharjyo, 1987), Bangladesh, Burma, southern China (Sichuan, Guanxi, Yunnan - Zhao, 1990; Zhao and Adler, 1993), Thailand (absent or rare in north and north-east, common elsewhere), northern Malaysia, Cambodia and Vietnam, north to at least Hue; recent records from northern Vietnam (Szyndlar and Nguyen Van Sang, 1996) require confirmation, as confusion with the superficially similar *Naja atra* is possible. *N. kaouthia* is also likely to occur in southern Laos, Bhutan and southern Nepal. A previous report of "*Naja naja kaouthia*" from Nepal (Kramer, 1977) was in fact based on misidentified specimens of *N. naja* (Wüster and Thorpe, 1992a).

DESCRIPTION

Size.- Most adults measure 110-150 cm. Record size is approximately 230 cm.

Colour pattern.- The colour pattern of the monocellate cobra is fairly variable. The ground colour is generally some shade of medium to dark brown or grey-brown, or blackish. Many specimens are uniform, others show some banding. The type of pattern varies geographically. In Bengal and the Gangetic Plain, many specimens are conspicuously banded. The light bands are wide in the anterior part of the body, and become narrower as one goes back along the body, dividing into double, then quadruple bands in the process. In the posterior third to two-thirds of the body, they often become difficult to identify as individual bands, and form a strongly contrasting reticulate pattern instead. The pattern tends to be most strongly contrasting in the posterior portion of the animal, and is illustrated in Whitaker (1978). Specimens from other areas tend to have a less strongly patterned body, and may be uniform except for the hood mark, which is almost always present in this species, although it may be faint.

Hood mark.- The hood mark of this species usually consists of light circle with a dark centre, but may sometimes be mask-shaped, with further dark spots in the light fields of the circle. In some specimens, the hood mark is connected to the light throat area. Occasionally, the hood mark may be "scrambled", making it impossible to assign it to one of the "standard" hood mark shapes, but this is rare in India. See Cox (1991) for photographs of hood mark variation in this species in Thailand.

Most specimens of the monocellate cobra have a very distinct throat pattern. The light throat colour generally extends less far backwards than in sympatric Indian spectacled cobras (*Naja naja*), although there is overlap. There is one pair of small lateral throat spots, which are restricted to the outer edge of the ventrals and the lowest row of dorsal scales. Occasional specimens have more than one pair, some have none.

TABLE 7: Scalation of *Naja kaouthia*. Specimens from the Gangetic Plain tend to have dorsal scale row counts near the lower end of the range indicated here.

	Males		Females	
	Range	Mean ± S.D.	Range	Mean ± S.D.
Ventrals	170 - 192	180.43 ± 4.67	178 - 197	186.51 ± 4.13
Subcaudals	48 - 61	54.66 ± 2.52	46 - 59	52.20 ± 2.62
Cuneates	1 - 6	3.32 ± 1.12	1 - 6	3.63 ± 1.26
Posterior temporals	4 - 9	6.46 ± 0.97	4 - 9	6.37 ± 1.00
Nuchals	5 - 10	6.70 ± 1.01	5 - 9	7.41 ± 0.91
Dorsals at 10th ventral	26 - 34	29.26 ± 1.62	24 - 33	29.08 ± 1.82
Dorsals at 20% ventral count	19 - 23	21.09 ± 0.72	19 - 23	21.01 ± 0.66
Dorsals at 40% ventral count	19 - 23	21.20 ± 0.79	19 - 23	21.05 ± 0.71
Dorsals at 60% ventral count	17 - 21	19.80 ± 1.03	17 - 21	19.61 ± 1.11
Dorsals at 80% ventral count	14 - 17	15.16 ± 0.57	15 - 17	15.25 ± 0.60
Dorsals at vent	14 - 19	15.85 ± 1.04	15 - 18	15.86 ± 0.97

The ventral coloration is variable in this species. Most specimens have a clearly defined dark band behind the light throat, followed by a light band, followed by another dark band, followed by a mottled light area, which becomes darker posteriorly until the entire ventral surface is dark. The underside of the tail is usually light, but often suffused with dark pigment. The subcaudals often have conspicuous dark edges.

In Thailand, uniformly yellowish or cream-coloured specimens are found in parts of the central plain. These are sometimes referred to as "Suphan cobras" (Cox, 1991), but are variants of no taxonomic significance (Wüster et al., 1995).

Scalation.- The most notable features of the scalation of this species are a tendency to have more than one cuneate scale on each side, unlike the other Asiatic cobra species, and the shape of the frontal scale: in *Naja kaouthia*, this is conspicuously short and square, being almost as broad as, or broader than, long, and much shorter than its distance from the rostral scale. Table 7 summarises the variation found in selected scalation characters in this species.

Dentition.- The largest fang recorded in this study measured 6.78 mm, and was measured in a male specimen from Bengal measuring 1555 mm in total length. The fangs of this species are moderately adapted for spitting in that the venom discharge orifice is shorter than in the non-spitting *Naja naja* and *N. oxiana*, and terminates further from the tip of the fang than in those species (Wüster and Thorpe, 1992b). Variation in tooth counts is summarised in Table 8.

DIAGNOSIS

In India, *Naja kaouthia* occurs sympatrically with *N. naja* in much of northern and north-eastern India. Characters that can distinguish between these two forms are given in Table 4. The shape of the hood mark alone is usually sufficient to distinguish these two forms. *N. kaouthia* is not known to be sympatric with *N. oxiana*, but the higher ventral and subcaudal scale counts of the latter, coupled with the absence of a hood mark

TABLE 8: Dentition of *Naja kaouthia*.

	Males		Females	
	Range	Mean ± S.D.	Range	Mean ± S.D.
Palatine teeth	6 - 9	6.98 ± 0.51	5 - 8	6.86 ± 0.60
Pterygoid teeth	10 - 17	13.01 ± 1.47	10 - 17	13.30 ± 1.49
Dentary teeth	13 - 17	14.00 ± 0.66	13 - 15	13.84 ± 0.45
Solid maxillary teeth	1 - 2	1.04 ± 0.20	0 - 1	0.97 ± 0.18

and lateral throat spots make differentiating between these two species simple.

NATURAL HISTORY

Habitat.- In areas where *Naja kaouthia* occurs sympatrically with other *Naja* species, it generally tends to occupy low-lying, wetter areas than those occupied by other species. This has been observed in the zone of sympatry between *N. kaouthia* and *N. naja* in northern India (Sights, 1949). This species adapts well to human presence, unless persecuted excessively. It is common in rice-growing areas, where it lives in rodent burrows in the dykes between the fields; in some such areas, it has become almost semi-aquatic. Various plantations are another favourite haunt.

Reproduction.- Egg-laying, like all cobras. Egg-laying takes place in January-March (Whitaker, 1978). The female generally stays with the eggs. Some collaboration between male and female in guarding eggs has been reported in *Naja naja* x *N. kaouthia* hybrids (Campbell and Quinn, 1975).

Food.- Juveniles take mostly amphibians, adults also eat small mammals. Snakes and fish are also eaten occasionally.

Behaviour.- Most active at dusk and in the evening, but may also be encountered at other times. Generally rather quieter and less excitable than other cobras, but shows considerable individual variation. Like all cobras, will flee if encountered, and only faces an adversary if cornered. The fangs of this species are somewhat adapted for spitting venom, but spitting is apparently very rare in this species. However, instances of spitting in cobras were recorded by Goring Jones (1900 - Mandalay, Burma), Shaw and Shebbeare (1930 - north-eastern India and Sikkim) and Dickinson (1945 - Sundarbans and Assam). The specimens were not adequately described, but the common cobra species of these areas is *N. kaouthia*. Spitting of some form was also attributed to cobras identifiable as *N. kaouthia* by Duckett (1964), from Malaysia.

MEDICAL IMPORTANCE

Naja kaouthia is an important cause of snakebite mortality and morbidity in much of its range (Reid, 1964; Looareesuwan et al., 1988; Viravan et al., 1986, 1992). Its importance in India relative to that of the spectacled cobra (*N. naja*) is unknown, but Acharji and Mukherjee (1966) considered it a pest in parts of Bengal, and blamed it for many fatal bites. Outside India, bites by this species have been the subject of two in-depth studies by Reid (1964) and Viravan et al. (1986). Symptoms included both neurotoxic effects and necrosis, which was extensive in some cases. Bites by this species in India have not been studied in any detail. Geographic variation in venom composition is possible. A series of bites from northern Malaysia (Reid, 1964) suggested a substantially higher incidence of necrosis and a lower incidence of neurotoxic symptoms than a later study in Thailand (Viravan, 1986); however, the study of Reid (1964) is difficult to evaluate, as some of the snakes involved were *N. sumatrana*.

NAJA SAGITTIFERA WALL, 1913A - ANDAMAN COBRA

Naia tripudians var. *sagittifera* Wall, 1913a.

Naja kaouthia sagittifera - Deraniyagala, 1961.

Naja naja sagittifera - Klemmer, 1963.

Naja naja kaouthia - Whitaker, 1978.

Naja kaouthia - Wüster and Thorpe, 1991.

DISTRIBUTION

Restricted to the Andaman Islands. Recorded with certainty only from South Andaman, but is also likely to occur on North and Middle Andaman, and possibly on other islands in the group.

DESCRIPTION

Size.- Adult size is unknown, as the only few specimens available in scientific collections are juveniles, the longest measuring 635 mm in total length.

Pattern.- The dorsal ground colour of the known juvenile specimens is dark, whereas the ventral side is light. On each side, light lines rising up from the ventral side form a series of irregular, triangular or shark-fin-like outlines on the sides of the animal. The pattern has been described as a series of white A-shaped marks

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THE GENUS *DABOIA* (SERPENTES: VIPERIDAE): RUSSELL'S VIPER

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(with one text–figure)

ABSTRACT.- The systematics and natural history of Russell's viper (*Daboia russelii*, formerly *Vipera russelii*) are reviewed. The two recognised subspecies (*D. russelii russelii* and *D. russelii siamensis*) are described, and the available literature data on systematics, distribution, natural history and medical importance are summarised, with particular emphasis on the geographic variation in venom composition and clinical effects found in this species.

KEY WORDS.- *Daboia russelii*, Vipera, Serpentes, taxonomy, morphology, natural history, venom.

INTRODUCTION

The genus *Daboia* is represented by a single species, *Daboia russelii,* the Russell's viper. This species is widespread in many parts of south-east Asia, and is a major cause of snakebite morbidity and mortality in most of its range. Russell's viper was until recently classified as a species of the genus *Vipera*, and is therefore better known as *Vipera russelii*. Obst (1983) revived the genus *Daboia* Gray, 1842, and assigned *Vipera russelii* and other large members of *Vipera*, as it was then understood (such as *V. lebetina, V. mauritanica, V. xanthina* and *V. palaestinae*), to *Daboia*. However, this was not universally followed (e.g., Joger, 1984; Brodmann, 1987; de Silva, 1990; Wüster et al., 1992a,b). Herrmann et al. (1992) examined the phylogeny of Eurasian viperines, using albumin immunology and blood serum electrophoresis. Their results show *Vipera russelii* to occupy an isolated position, the species being only distantly related to other Eurasian viperines, and they proposed the revalidation of *Daboia* as a monotypic genus, with *D. russelii* as the only species. The other large Eurasian viperines were classified as *Vipera* (*V. xanthina* and allied species), or assigned to the revalidated genus *Macrovipera* Reuss, 1927 (*V. lebetina* and related species). The restriction of *Daboia* to the single species *russelii* was followed by Golay et al. (1993) and Welch (1994).

DABOIA RUSSELII (SHAW & NODDER, 1797) - RUSSELL'S VIPER

Coluber russelii Shaw & Nodder, 1797.
Daboia russellii Gray, 1842.
Daboia elegans Gray, 1842.
Daboia pulchella Gray, 1842.
Vipera russellii Strauch, 1869.
Vipera russelli Wall, 1907.

DISTRIBUTION

The species *Daboia russelii* has a vast distribution which extends somewhat discontinuously across most of southern Asia, and into the islands of Indonesia. It occurs in many parts of Pakistan, more or less throughout India, Bangladesh and Sri Lanka, as well as in Bhutan and parts of Nepal. Further east, it is found in Taiwan and in parts of Burma, Thailand, China, and on eastern Java and some of the Lesser Sunda Islands.

INTRASPECIFIC SYSTEMATICS OF *DABOIA RUSSELII*

Until recently, the vast and discontinuous distribution of this species had led to a number of subspecies being described from different parts of its range. Most authors (e.g., Harding and Welch, 1980; Leviton, 1968) recognized five subspecies of Russell's viper: *V. r. russelii* (Shaw, 1797) from India, Pakistan and Bangladesh; *V. r. pulchella* (Gray, 1842) from Sri Lanka; *V. r. siamensis* Smith, 1917, from Burma,

Thailand, Cambodia and southern China; *V. r. formosensis* Maki, 1931, from Taiwan; and *V. r. limitis* Mertens, 1927, from Java, Komodo, Flores and Lomblen. In addition, Kopstein (1936) described the Javan populations as *V. r. sublimitis*, and Deraniyagala (1945) the northern Indian populations as *V. r. nordicus*. The subspecies *V. r. sublimitis* was recognized by van Hoesel (1954, 1958), but *V. r. nordicus* has been ignored by subsequent workers. These subspecies were defined primarily on the basis of the number of rows of dorsal spots, and a few other colour pattern characters; in some cases, purported differences, especially in the number of rows of dorsal spots, were artifacts, caused by a misinterpretation of previous published descriptions (Brongersma, 1958). The pronounced similarity between some populations assigned to different subspecies has been noted (Brongersma, 1958; Warrell, 1989).

Wüster et al. (1992a; 1992b) re-examined the systematics of *Daboia russelii*, using multivariate analysis of large numbers of morphological characters, and recognised only two subspecies of *Daboia russelii*: a western subspecies, *Daboia russelii russelii*, from India, Pakistan, Sri Lanka and neighbouring areas (including the old subspecies *russelii, pulchella* and *nordicus*), and *Daboia russelii siamensis* from Burma and the more eastern parts of the distribution (including the old subspecies *siamensis, formosensis, limitis* and *sublimitis*). It was noted that, within the latter subspecies, the specimens from the Lesser Sunda Islands differed considerably from the specimens from Java and the Asiatic mainland.

Wüster et al. (1992b) noted that the question of whether these forms should be regarded as subspecies or as separate species depends on the species concept used. Since the two forms are allopatric, there can be no conclusive evidence of reproductive isolation, or lack thereof. Consequently, the biological species concept, which relies on this criterion, is inoperative in this situation. Adherents of the phylogenetic or evolutionary species concepts (e.g., Wiley, 1981; Cracraft, 1989) would split Russell's viper into two or even three species. However, Wüster et al. (1992b) regarded an understanding of the pattern of geographic variation in this group as more important than a decision on taxonomic rank, which is dictated by a subjective decision on the species concept to be used. Further studies on the population systematics of the *D. russelii* group are currently in progress, and it was therefore felt to be premature to alter the nomenclature more than absolutely necessary at this time.

The confusion that would result in the biomedical literature from a formal split of Russell's viper into two or more species at the same time as other workers were moving it from the genus *Vipera* to the genus *Daboia* makes a conservative approach particularly important in this case. Consequently, Wüster et al. (1992b) proposed a conservative approach, in which the Russell's viper group is regarded as a single species with two subspecies, *D. r. russelii* being the western form, and *D. r. siamensis* the eastern form.

In the following paragraphs, separate descriptions of the two subspecies will be provided. However, natural history and venom information will be provided jointly for both forms, although the geographic locality to which the information pertains will be noted where necessary.

Distinguishing between *Daboia r. russelii* and *D. r. siamensis*.- The two subspecies of Russell's viper can be easily distinguished: *D. r. russelii* has a total of three rows of distinct, ovoid spots, one on each side and one along the middorsal line. Any marking between these three rows consists at most aggregations of small black speckles. In *D. r. siamensis*, there are further rows of smaller, well-defined spots between the three main rows found in *D. r. russelii* (Fig. 1). The difference appears to be absolutely diagnostic, and has also been illustrated in Warrell (1989) and Cox (1991). There are no contact zone between the two subspecies, and therefore no intergrades which might confuse the situation.

DABOIA RUSSELII RUSSELII (SHAW & NODDER, 1797)

Vipera russelli nordicus Deraniyagala, 1945.
Vipera russelli pulchella Deraniyagala, 1945.
Daboia russelli russelli Obst, 1983.
Daboia russelli pulchella Obst, 1983.

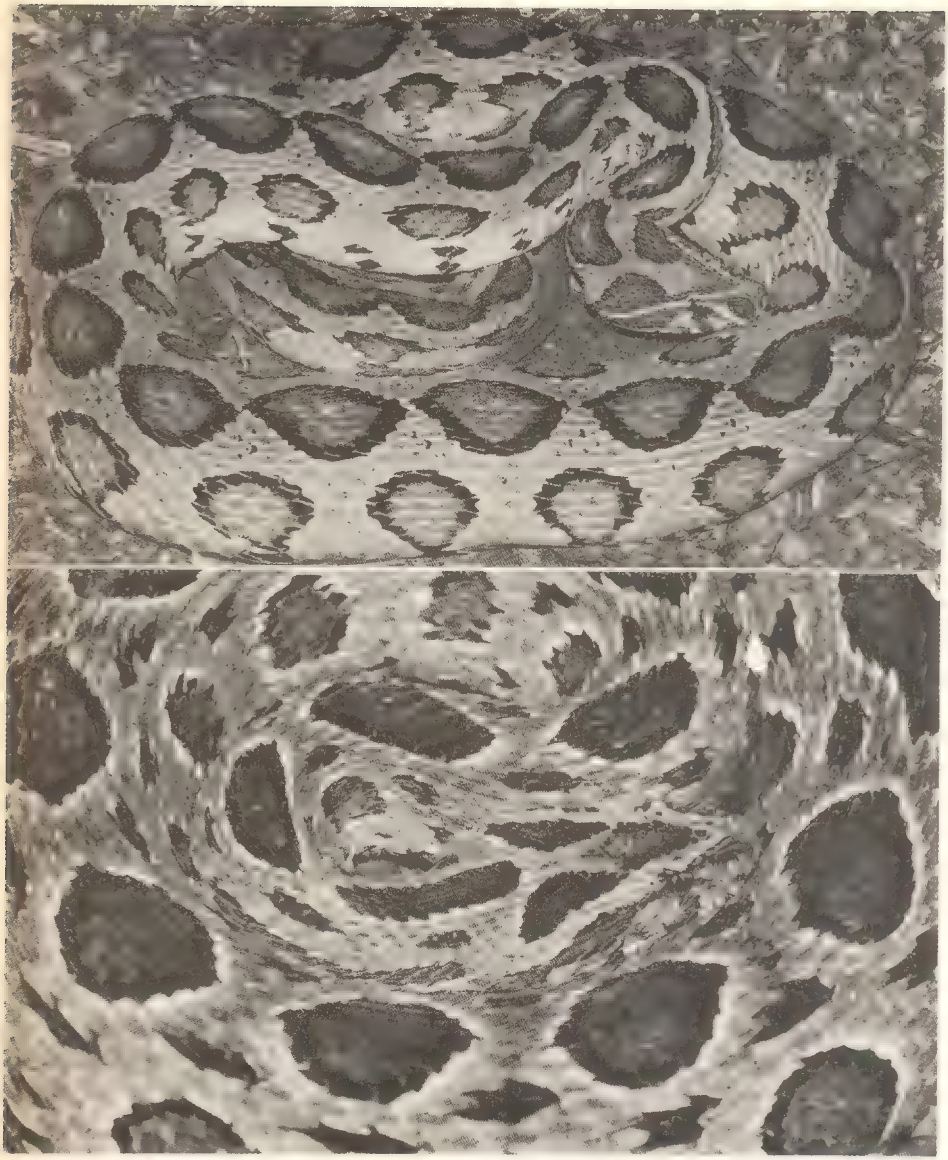

FIGURE 1: Pattern of *Daboia russelii russelii* (top: specimen from Sri Lanka) and *D. r. siamensis* (bottom: specimen from Thailand). Note the presence of additional rows of well-defined smaller spots between the principal rows in the Thai specimen; these are never present in *D. r. russelii*, which has at most groups of small speckles between the main rows, as seen here.

DISTRIBUTION

The subspecies *Daboia russelii russelii* is found more or less throughout India, although its range is somewhat discontinuous, and it may be rare in some areas, and very common in others. It appears to be absent in Assam and neighbouring states, although it is found in Bhutan and Darjeeling. Reported to be very common in the Punjab, along the west coast, and many parts of southern India; rarer in the Ganges Valley and northern Bengal (Smith, 1943). Has been found in western Nepal (O'Shea, pers. comm.). In Pakistan, it is

restricted to the northern Punjab and neighbouring areas, and the Indus Valley in Sind Province (Joger, 1984; Khan, 1990).

DESCRIPTION

Size.- Most adults measure about 100-120 cm, one record is approximately 167 cm (Smith, 1943), but Murthy (1990) puts the maximum size at 185 cm.; neonates measure 20-30 cm, and are exact replicas of the adults.

General appearance.- A fairly stout, robust snake with a fairly short tail and a thin neck. Head very distinct from body, somewhat triangular. Pupil of eye vertical. Nostril very large.

Pattern.- *Daboia russelii russelii* has a characteristic pattern which makes it difficult to confuse it with any other Indian snake species, if carefully observed. Dorsal ground colour usually some shade of brown. Three rows of oval spots along the body, one along the midline, and another along each side. Sometimes, some small darkish speckles between these main rows. These spots are normally brown in the center, and have a black or dark brown outer margin, which in turn has a very fine white outer margin (see Brongersma, 1958, for a more detailed analysis of pattern variation in Russell's viper). Normally two oval or triangular spots with black and white margins on each side of the top of the head. Ventral surface white, with numerous small, half-moon shaped marks on many ventral scales.

Scalation.- Males have 163-175 ventrals and 44-64 subcaudals, females have 160-175 ventrals and 45-56 subcaudals. Dorsal scales keeled, in 27-32 (most commonly 29) rows at midbody (defined as the level of 50% of the total ventral scale count). Upper side of head covered in small scales, only the supraoculars being noticeably differentiated. Seven to 11 small scales separate the supraoculars. Supralabials 9-13. Infralabials 12-17.

DABOIA RUSSELII SIAMENSIS (SMITH, 1917)

Vipera russelli siamensis Smith, 1917.
Vipera russelli formosensis Maki, 1931.
Vipera russelli limitis Mertens, 1927.
Vipera russelli sublimitis Kopstein, 1936.
Daboia russelli limitis Obst, 1983.

DISTRIBUTION

Daboia russelii siamensis has a strikingly discontinuous distribution. It is very common in the central plains of Burma. In Thailand, it occurs in the central plain from Nonthaburi Province north to Kamphaeng Phet province, and east to Nakhon Ratchasima Province, and through Prachinburi Province and into adjacent Cambodia near Aranyaprathet and Pailin (Saint Girons, 1972; Viravan et al., 1992). Reports from more southerly parts of Thailand (Cox, 1991) require confirmation. It is also found in parts of southern China, in the provinces of Guangxi, Guangdong and southern Fujian (Zhao, 1990; Zhao and Adler, 1993), as well as in southern and eastern Taiwan (Lin, 1990). In Indonesia, it has a small and scattered range: it is found in the region of Surabaya and Tuban in eastern Java (van Hoesel, 1959; Hodges, 1993; Belt, 1997), and the lesser Sunda Islands of Komodo, Flores, Endeh, Lomblen, Adonara, and Solor (van Hoesel, 1954, 1958; Auffenberg, 1980; Warrell, 1989; Belt et al., 1997).

DESCRIPTION

Size.- This form appears to remain smaller than the western subspecies. Specimens from the Lesser Sunda Islands very rarely reach 100 cm (Auffenberg, 1980, reported a maximum snout-vent length of 70 cm in his series), those from Java have been recorded at up to 111 cm. The largest specimen in two large series from Burma (Myint-Lwin et al., 1985; Tun-Pe et al, 1991) measured 112 cm. Neonates in Burma measure 22 cm on average, but specimens as small as 12.5 cm have been reported from the same country (Tun-Pe et al., 1991). The smallest specimen from Komodo noted by Auffenberg (1980) measured 17 cm in snout-vent length, suggesting a total length of over 20 cm.

Pattern.- The pattern of *D. russelii siamensis* is very similar to that of the nominate form. The main difference is the presence of further rows of spots between the three principal rows (see Brongersma, 1958, for a more detailed analysis of pattern variation in Russell's viper). There are other subtle differences in pattern, and there is also geographic variation in pattern distinctness, ground colour etc. within *D.r. siamensis*.

Scalation.- Males have 146-167 ventrals and 42-61 subcaudals, the females have 146-166 ventrals and 33-58 subcaudals. Dorsal scales keeled, in 27-33 (normally 29-31) rows at midbody (defined as 50% of ventral scale count). Top of head covered in small scales, only the supraoculars being differentiated. Six to 10 small scales separate the supraoculars. Supralabials 9-12. Infralabials 11-14.

NATURAL HISTORY OF *DABOIA RUSSELII*

Habitat.- Russell's viper is primarily an inhabitant of fairly open areas, with grassy, scrubby or bushy vegetation. Also found in rice fields and other agricultural areas. May take refuge in rock crevices, termitaria or the base of bushes. Occurs from sea level to 2100 m in southern India, to a slightly lesser altitude in the western Himalayas. In Thailand, it has only been reported from fairly low-lying parts of the central plain. On Komodo, Auffenberg (1980) reported it from savanna and beachside habitats at low altitudes (0-120 m), often in association with dry river beds and stone piles.

Reproduction.- Russell's viper is ovoviviparous, i.e., it gives birth to fully developed young, which normally number 20-40. Litters of up to 63 neonates have been reported (Wall, 1906). In India, birth normally occurs from May to July, whereas Auffenberg (1980) collected neonates in January on Komodo.

Food.- Adults are generally reported to eat mostly rodents, but there is considerable geographic variation in diet, which may reflect variation in prey availability. In southern India, gerbils (*Tatera indica*) are reported to be the main food (Whitaker, 1978). Juveniles from India have been reported to eat pretty much any vertebrate they can overpower, including young conspecifics, and have even been reported to eat land crabs, scorpions and other arthropods (Whitaker, 1978). A series of stomach contents from specimens of all sizes (21 out of 34 were juveniles under 40 cm) from Burma consisted overwhelmingly of rodents (29 out of 34), with only very few frogs, lizards and birds. On Komodo, juveniles were found with insects, especially coleoptera, in their digestive tract, and adults and juveniles alike were found to contain lizards, rodents and anurans (Auffenberg,1980)

Behaviour.- Mostly nocturnal, very occasionally encountered active during the day. Reported to be generally slow-moving. Will often stand its ground when disturbed in the open. When disturbed, hisses very loudly and stridently. Once irritated, strikes rapidly and with great force. Some specimens thrash around wildly, striking in all directions. Can move with surprising rapidity in such circumstances.

MEDICAL IMPORTANCE

Due to its occurrence in agricultural areas (especially rice fields), its excellent camouflage, uncertain temper and potent venom, Russell's viper is a major cause of snakebite morbidity and mortality in many areas, such as India (Matthai and Date, 1981), Sri Lanka (Phillips et al., 1988; de Silva, 1981, 1990; de Silva and Ranasinghe, 1983), Burma (Aung-Khin, 1980; Myint-Lwin et al., 1985), Thailand (Looareesuwan et al., 1988; Sawai et al., 1972) and parts of Indonesia (Auffenberg, 1980; Belt et al., 1997).

Recent work on the clinical effects of the venom of Russell's viper, carried out in many parts of its range, has revealed an enormous degree of geographic variation in the syndrome of envenomation experienced by human bite victims (summarised by Warrell, 1989; 1995; 1997; Belt et al., 1997). Reduced blood coagulability and renal failure are widespread, but a number of other phenomena show strong geographic variation. Bites in Sri Lanka also result in neurotoxicity, rhabdomyolysis and intravascular haemolysis (Jeyarajah, 1984; Phillips et al., 1988). Neurotoxic effects have also been reported from southern India. Pituitary haemorrhage has been reported from southern India and Burma (Myint-Lwin et al., 1985; Warrell, 1986, 1989). Bites in Burma result furthermore in shock and generalised capillary permeability, whereas bites in Thailand result mostly in intravascular haemolysis and reduced blood coagulability. There is a serious shortage of detailed reports of the clinical effects of the bites of this species from India, Pakistan, Bangladesh, China, Taiwan and Indonesia.

These differences in clinical symptoms are related to profound differences in venom composition and enzymatic activity (Jayanthi and Gowda, 1988; Woodhams et al., 1990), which in turn may affect antivenom efficacy if an antivenom is used against the venom of populations other than those used for its preparation.

Antivenom effectiveness in Russell's viper is apparently not related to the principal division into eastern and western subspecies, and also not necessarily to differences in the effects of the venom. Despite profound differences in clinical venom effects, antivenom against Burmese Russell's viper (*Daboia r. siamensis*) was found to be effective against the venom of Thai Russell's vipers (also *D. r. siamensis*) and even against the venom of Russell's vipers from India (*D. r. russelii* - specific locality not noted, unfortunately) (Phillips et al., 1988). On the other hand, the Burmese antivenom was found to be ineffective in protecting mice against the lethal effects of Sri Lankan *D. r. russelii* venom (Phillips et al., 1988), as was Indian (Haffkine) antivenom, presumably produced from the venom of western Indian populations of *D. r. russelii.* The latter was found by Phillips et al. (1988) to be similarly ineffective in treating human patients envenomated by Russell's vipers in Sri Lanka. Jayanthi and Gowda (1988) mentioned reports of lack of efficacy of Haffkine antivenom when used in southern India, but Matthai and Date (1981) noted that Haffkine antivenom appeared to greatly reduce the incidence and severity of acute renal failure in children if administered within 2 hours of the bite. In Burma, monospecific Burma Pharmaceutical Industry antivenom administered even within 4 hours of the bite failed to prevent renal failure (Myint Lwin et al., 1985).

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A REMARKABLE NEW SPECIES OF RANID (ANURA: RANIDAE), WITH PHYTOTELMONOUS LARVAE, FROM MOUNT HARRIET, ANDAMAN ISLAND

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(with three text-figures)

ABSTRACT.- A new species of ranid, tentatively assigned to the genus *Rana* (sensu Boulenger, 1920) is described from Mount Harriet National Park, South Andaman Island, India. The new species, *R. charlesdarwini*, is diagnosed by the following suite of characters: tympanum large, exposed; lingual papilla absent; digit tips swollen but not dilated, lacking circummarginal grooves; ova pigmented, relatively numerous; the single adult male known smaller than two adult females and shows a median vocal sac and smooth nuptial pads on upper surface of first finger. Its phytotelmonous larvae from water-filled holes of trees have robust, dark-pigmented jaw sheaths that are situated terminally.

The new species appears allied to Indo-Chinese and Indo-Malayan ranids assigned to the genus *Ingerana* Dubois, 1987, although it shows numerous, relatively small, pigmented ova, and in lacking disks on digits and circummarginal grooves, as well as a median lingual papilla, cannot be placed in either of the two subgenera, *Ingerana* or *Liurana* Dubois, 1987. Generic placement of the Andamanese species is tentative, pending collection of further examples of its poorly known presumed relatives from south-east Asia, as well as data on their life history. The lowered sea levels during the post-Pleistocene are hypothesized to have facilitated the immigration of species from Indo-China, across the Rakhine (Arakan) Yoma corridor.

KEY WORDS.- *Rana charlesdarwini*, new species, Anura, Ranidae, systematics, Andaman Islands, India.

INTRODUCTION

Mount Harriet National Park (10° 43'-11° 51'N and 92° 43'-92° 47'E), comprises a series of mountains in the South Andaman Island, India. The summit of Mount Harriet is at an altitude of 365 m above msl. Forest types represented include tropical evergreen and moist deciduous forest. The landscape is undulating, with several hill ranges, and in the South Andamans, drainage flows into creeks that ultimately lead to the eastern shores (Oldham, 1885). The mineral composition of the soil includes gritty sandstones, siltstones and clays, locally with abundant nummulitic fossil contents, the microfossil assemblage indicating a Middle Eocene (Kirthar) age (Karunakaran, 1968).

An assessment of the vertebrate biodiversity of the region was conducted between 20 August and 3 September, 1997, in order to gather baseline data on species occurrence and habitat use. A series of a ranid, including larval stages, collected during these surveys was found new to science and is being described as a new species.

MATERIALS AND METHODS

The adults in the type series were hand collected; the larvae scooped out of a tree hole, both fixed in formalin. The adults were transferred to 70% ethanol within four months of collection. The larvae were retained in formalin. Measurements were taken with a MitutoyoTM dial vernier caliper (to the nearest 0.1 mm). Details of measurements have been provided in Das and Chanda (1997). In addition, length of digits were taken from the distal subarticular tubercle to the tip of the digits. Sex was confirmed through examination of the gonads. Nomenclature of adult colouration follows Smith (1975; 1981), colour notes taken from Fujichrome 100 ASA slide

transparency film. Larval staging is after Gosner (1960).

SYSTEMATICS

Rana charlesdarwini sp. nov.

Figs. 1–3; also back cover

Materials.- ZSI A8890 (holotype), adult male, ca. 0.3 km N of summit of Mount Harriet (10° 45'N and 92° 46'E), Mount Harriet National Park, South Andaman Island, Bay of Bengal, India; altitude 365 m above msl, collected by Indraneil Das, 17 August, 1997; ZSI A8891-92 (two paratypes), adult females, locality and collector as above, 30 August, 1997; ZSI A8893 (five paratypes), larvae, locality and collector as above, 22 August, 1997. The type locality is indicated in Fig. 3.

Diagnosis.- A member of *Rana* (sensu Boulenger, 1920, separable from members of other ranid generea from south-east Asia (see 'Affinities and Discussion') in showing the following characteristics: tympanum large, exposed; lingual papilla absent; digit tips swollen but not dilated, lacking circummarginal grooves; ova pigmented, relatively numerous; the single adult male known smaller than two adult females and shows a median vocal sac and smooth nuptial pads on upper surface of first finger. Its phytotelmonous larvae have robust, dark-pigmented serrated jaws situated terminally, and inhabits tree holes.

Adult description (based on holotype).- Small body size (SVL 26.4 mm); habitus somewhat slender, with narrow waist; head short (HL/SVL ratio 0.33), shorter than width (HL/HW ratio 0.83), snout flattened (HL/HD ratio 1.57); obtusely pointed, slightly projecting beyond mandible; nostrils closer to snout tip than to orbit (E-N/E-S ratio 0.57), canthus rostralis vertical in transverse section; lores concave; orbit large (ED/HL ratio 0.50), orbit diameter greater than orbit-nostril distance (ED/E-N ratio 1.57), interorbital distance x 1.5 times width of upper eyelid (IO/UE ratio 1.50); a weak dermal fold in interorbital region; internarial region narrow (IN/ED ratio 0.61); supratympanic fold present fleshy, commencing at posterior edge of orbit, and terminating at insertion of forelimbs; tympanum large, oval, flattened, slightly less than half orbit diameter (HTYD/ED ratio 0.52), situated posteroventrally to orbit, narrowly separated from orbit, and dorsal to angle of jaws, its greatest diameter at a vertical plane (HTYD/VTYD ratio 0.88). Nares laterally oriented, protuberant, and oval; vomerine teeth in two slightly oblique series, slightly posterior of choanae, separated by a distance over twice length of each group, choanae oval; inferior aspect of snout slightly nicked, inner margin of mandible juncture with a slight w-shaped notch, lacking odontoids near symphysis; tongue relatively large (7.9 mm in length), elongate (5.0 mm in width), its dorsal surface smooth, lacking a median papilla; bifid, free posteriorly for 69.6 per cent of length.

Fingers relatively short; tips of fingers with swollen tip but not disk-like, lacking circummarginal grooves; humeral glands absent. Toe tip (on finger III) 0.6 mm (14 per cent of orbit diameter); fingers free; relative lengths of fingers: 3 > 4 > 1 > 2.

Tibia short (TBL/SVL ratio 0.56); toes relatively long; tips of toes swollen, but not flattened into disks, lacking circummarginal grooves; webbing free on inner and outer edges of toe I and on inner edge of toe II; on outer edge of toe II, webbing is between disk and distal subarticular tubercle; on inner edge of toe III, webbing is between penultimate and distal subarticular tubercle; on outer edge of toe III, webbing is to distal subarticular tubercle; on inner aspect of toe IV, webbing is to penultimate subarticular tubercle, reaching base of disk as narrow sheath; on outer edge of toe IV, webbing is to penultimate subarticular tubercle, reaching base of disk as a narrow sheath; on inner edge of toe V, webbing reaches distal subarticular tubercle, reaching base of disk as a narrow sheath; and on outer edge of toe V, is a narrow sheath of skin reaching to base of disk. Tarsal fold weak; femoral gland absent; outer metatarsal tubercle weak, rounded; inner metatarsal tubercle distinct, elongated; relative lengths of toes: 4 > 5 > 3 > 2 > 1.

Body long (axilla-groin distance/SVL ratio 0.50); dorso-lateral body fold absent; lateral line system absent; dorsum of body shagreened, but lacking tubercles; tubercles dense over upper eyelids, throat and pectoral region smooth; lower part of venter up to inguinal region smooth; thigh

TABLE 1: Measurements (in mm) of the adults in the type series of *Rana charlesdarwini* sp. nov. (see text for details).

	ZSI A8890 adult male holotype	ZSI A8891 adult female paratype	ZSI A8892 adult female paratype
SVL	26.4	34.5	34.4
A-G	13.3	14.9	15.9
HL	8.8	10.1	11.4
HW	10.6	12.0	11.8
HD	5.6	6.8	6.1
ED	4.4	4.9	4.5
UE	2.8	3.0	3.2
IO	4.2	5.8	5.9
IN	2.7	3.5	3.3
E-S	4.9	5.4	5.7
E-N	2.8	3.5	3.3
E-T	0.5	1.4	1.5
TBL	14.8	20.0	19.6
HTYD	2.3	2.6	2.9
VTYD	2.6	2.7	2.8

venter smooth; undersurface of forelimbs and rest of hind limbs smooth; no gland present at posterior of upper labial; no lateral glands; cloacal opening directed posteroventrally; slightly below upper level of thighs.

Colouration.- Dorsum of body Mars brown; except forehead up to scapular region, which is chestnut; canthal region buff; upper surface of thighs Mars brown with vandyke brown bars; lips barred with dark brownish-olive; iris warm buff; pupil black. Ventrum of body cream.

Sexual dimorphism and dichromatism.- The single male is smaller than either of the two females, in addition to possessing a median internal vocal sac. The gular and pectoral regions of the ventrum bear intense dark pigmentation in the male, while being an unpatterned cream in females. The male also shows a pale, smooth nuptial pad on the dorsal surface of first finger. The females differ strikingly in colouration, the dorsum of body being greenish-olive with two spectrum yellow blotches, a smaller one at the occipital region, and a larger one at midbody. The tympanum is of salmon color. The upper surfaces of the thighs are unpatterned. Ventrum of body cream.

Miscellaneous remarks.- One of the female paratypes shows ossified omosternum that is forked at the base. Both females contain numerous (100) small (1.5-1.8 mm) pigmented ova.

Larval description.- Larval stages are assigned to the new species as they were found close to the calling male and females, and the larval stages of all other amphibians in the region are known.

A 5.4 mm body length (tail-tip missing) Stage 25 larva (ZSI A8893.1) shows the following characteristics (see Fig. 1): body light, depressed dorsally, (1.43% wider than high); elongate; guitar-shaped; ventral contour of body flat; snout rounded, with preocular region almost semicircular in dorsal view, sloping vertically; chondrocranium elements not visible through skin; eyes oriented dorsally; interocular distance greater than internarial distance; nares small, inconspicuous; located dorsally; narial opening circular; margin slightly protruding; spiracle sinistral. The tail tip is damaged. In a Stage 22 larva (ZSI A8893.2), the caudal musculature fails to reach tail tip, terminating in a narrow point; caudal fin narrower than caudal musculature (at midlength); tip of tail rounded; lateral line system not evident.

Oral apparatus directed distally (Fig. 2), oral disk bordered by small papillae; both jaw sheaths robust, infrarostrodont slightly larger than suprarostrodont, the latter with relatively more acute serrations on edges that are subtriangular,

TABLE 2: Measurements (in mm) of fingers and toes of the adult in the type series of *Rana charlesdarwini* sp. nov.

	Fingers				Toes				
	1	2	3	4	1	2	3	4	5
ZSI A8890	3.0	2.7	4.0	3.3	2.8	3.8	5.7	8.7	5.8
ZSI A8891	3.3	3.1	4.0	3.5	2.8	3.9	6.0	9.3	5.5
ZSI A 8892	2.8	2.4	3.3	2.7	2.5	3.2	4.9	6.8	5.1

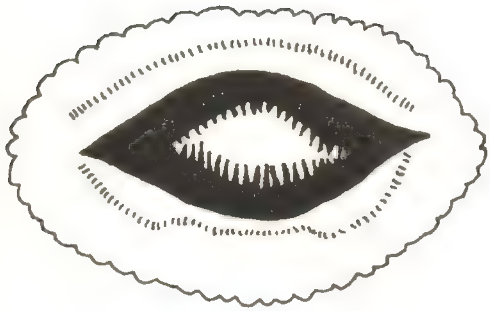

FIGURE 1: Oral apparatus of a Stage 25 larva of *Rana charlesdarwini* (ZSI A8893.1)

lanceolate, with acutely tapering tips on the infrarostrodont. Single labial teeth rows, each on the anterior and posterior labium.

Colouration (in preservative): body skin greyish-pink, with a darker lateral aspect of body and a dark stripe from beyond head along tail; caudal fins greyish, with darker bands, semitransparent. Body length 5.4 mm; body height 2.3 mm; body width 3.3 mm; tail height 2.2 mm; interorbital distance 0.1 mm; eye-snout distance 1.5 mm; eye-naris distance 0.6 mm; internarial distance 0.7 mm. The following measurements were taken on a Stage 22 larva (ZSI A8893.2): total body length of 12.3 mm; body length 3.2 mm; body height 1.7 mm; body width 2.5 mm.

Etymology.- The specific name honors Charles Erasmus Darwin (1809-1882), co-founder (along with Alfred Russel Wallace) of the theory of organismic evolution. These researches in the Andaman Islands were supported by the Darwin Initiative for the Survival of Species.

Natural history notes.- The male holotype was found calling from a water-filled hole of a tree, 67 cm from substrate, at 1255 hours. Also noticed in the same microhabitat were larval stages of mosquitoes. The females paratypes were found on the forest trail during a heavy thundershower, between 1310 and 1335 hours. Larval stages of the species were found close to the collection site of the two female paratypes, in the water-filled hole of a tree of 27 dbh, 177 cm above substrate. The cavity was 75 mm deep, at the edge of the forest trail, and exposed to sunlight. The tadpoles were found suspended on the water column in a head-up position. To inhale air, they rose to the surface with their head up, descending thereafter in a head-up position, remaining at the bottom with only their tails in contact with the substrate. The oral structure is suggestive of a diet of small invertebrates (such as insect larvae) or eggs of conspecifics.

The following amphibians were also recorded from the summit of Mt. Harriet: *Bufo melanostictus, Rana limnocharis* and *Kaloula baleata*. In addition, *R. andamanensis* was recorded from close to sea level to up to ca. 150 m above msl, just outside the boundaries of the National Park.

AFFINITIES AND COMPARISON

Assignment of the metamorphosed series comprising an adult male and two adult females to a genus is at the moment difficult, in the absence of working definitions to some of the genera of the south-east Asian Ranidae (see Inger, 1996). Here, I adopt a conservative stance in allocating

FIGURE 2: Lateral view of Stage 25 larva of *Rana charlesdarwini* (ZSI A8893.1). Tail tip missing and restored from a Stage 22 larvae (broken outline). Marker = 5 mm.

the species tentatively to the genus *Rana* (sensu Boulenger, 1920).

The new species from the Andamans is clearly not a member of the following south-east Asian genera of ranids (only opposing characters listed): *Amolops* (larvae with abdominal suckers, with lotic habits; cluster of glands present ventrally; digit-tips of adults with disks); *Huia* (scattered glands on dorsum of larvae, lower denticles over five pairs; suprarostrodont 'M'-shaped; digit-tips of adults with disks); *Meristogenys* (suprarostrodont divided in larvae; outer surfaces of jaws ribbed [see Yang, 1991: Fig. 3] digit-tips of adults with disks); *Occidozyga* (absence of denticles and papillae in larvae and of vomerine teeth in adults); *Platymantis* (absence of a free-living larva; large, unpigmented eggs that are few in number; reduced toe webbing in adults; fused metatarsals); and *Staurois* (larvae with abdominal suckers; digit-tips of adults with disks and omosternal style not forked).

The Andamanese species is obviously not conspecific with *Micrixalus borealis* Annandale, 1912 (distribution: Xizang and northeastern India; see Zhao and Adler, 1993), which has been assigned to the genus *Phrynoglossus* by Dubois (1987), showing the following features (and therefore indicating its membership of yet another lineage): vomerine teeth absent; oval tongue; tips of digits disk-like, bearing circummarginal grooves and tympanum indistinct.

The new Andamans species shares the most number of character states with that ranid catch-all genus, *Micrixalus* Boulenger, 1888 (type species: *Ixalus fuscus* Boulenger, 1882) sensu Frost, 1985, such as: small body size (SVL 26.4-34.5 mm); ossified omosternum forked at the base; tongue free, notched at the rear, lacking a median lingual papilla; vomerine teeth present; tympanum distinct, measuring about half orbit diameter; fingers free; toes webbed; external metatarsal tubercle present; skin of dorsum shagreened; skin of ventrum smooth; adult male with a vocal sac, and lacking femoral glands. *Micrixalus* comprises a lineage from south-western India (the Western Ghats forests), with seven valid nominal species (Pillai, 1978; 1981; Pillai and Pattabiraman, 1990). An additional 10 species from south-east Asia that are apparently not closely related, even to each other, have also been allocated, with hesitation, to the genus (Zhao and Adler, 1993; Inger, 1996), adding to the polyphyletic nature of the genus. The latter group of species have been reallocated to the genera *Ingerana* and *Phrynoglossus* by Dubois (1987; 1992), and only the south-west Indian species retained in *Micrixalus* sensu stricto. Inger (1996) has argued against the uncritical acceptance of this scheme of classification (see Duellman, 1993) on the basis that many of the characters that supposedly diagnose these genera are assumed rather than known. In the following section, I shall show that several of the characters (morphological as well as life history) considered by Dubois (1987) to be diagnostic of the genus *Ingerana* (the members of which apparently otherwise related to *Rana charlesdarwini*) are exhibited by the new species.

For the cooccurrence of an important character, the undilated digital disks that lack circummarginal grooves, the new species is considered closest to the Chinese species of *Micrixalus* that have been assigned to the subgenus *Liurana* Dubois, 1987. The new species is here compared with its members, and only characters that separate them are listed: *M. liu* (Yang, 1983) (distribution: Yunnan and Xizang, China), larger adult male size (32.7 mm), tips of fingers with transverse grooves; lingual papilla present [although Grant et al., 1997, mentioned that muscular protraction during preservation can produce a prominent lingual bulge in frogs]; *M. reticulatus* (Zhao and Li, 1984) (distribution: Xizang, China), toe tips dilated; vomerine teeth absent; tympanum concealed; dorsum of body with dermal folds; and *M. xizangensis* (Hu, 1977) (distribution: Xizang, China), vomerine teeth absent; tips of fingers with transverse grooves; and finger II I.

Even assuming that *Ingerana* is a good genus, and the Andamanese species is a member, a subgeneric allocation of the material within Dubois' (1987) scheme of classification is difficult, given the absence of disks at the tip of digits and of circummarginal grooves (a character associated with the subgenus *Liurana*) and the absence of lingual papilla (which, according to the original description, diagnose the subgenus

Ingerana). In addition, the number, size and pigmentation of ova does not support the predicted character states for members of the genus *Ingerana* Dubois, 1987. As Inger (1996) pointed out, these have been based on characters known from three of nine known species assigned to the genus *Ingerana*. The reproductive characters, on their own, do not justify the creation of yet another ranid genus, and in combination with the absence of lingual papilla, break down the two subgenera of *Ingerana*.

In the following section, the new species from the Andaman Island has been compared with congeners from south-east Asia. These are the species referred to *Ingerana* by Dubois (1987). Only characters separating south-east Asian congeners are listed. *Micrixalus baluensis* Boulenger, 1896 (distribution: north-western Borneo; see Inger, 1966; Inger and Stuebing, 1989), head length equals width; digit tips with disks bearing circummarginal grooves; ventrum granular; nuptial pads absent; and eggs unpigmented, 2.2-2.5 mm in diameter; *M. sariba* Shelford, 1905 (distribution: Borneo; see Inger, 1966). This species was tentatively considered a synonym of *M. baluensis* by Inger, 1954, and earlier by van Kampen (1923: 241), but revived as a distinct species by Dubois (1987), digits tips disk-like, with circummarginal grooves; SVL 38 mm; *M. mariae* Inger, 1954 (distribution: Palawan in the Philippines; see Inger, 1954), vocal sac absent; digits with disks showing circummarginal grooves; no outer metatarsal tubercle; and pectoral and abdominal regions rough; *M. tenasserimensis* Sclater, 1892 (distribution: southern Myanmar and Thailand; see Berry, 1975; Taylor, 1962), vomerine teeth typically absent; finger II finger I; toes webbed at base; outer metatarsals bound together; a pair of dorsolateral stripes from the posterior corner of the eyes; skin glassy smooth; and 2-3 large (diameter 2.5 mm) eggs in a clutch; and *M. tasanae* (Smith, 1921) (distribution: southern Thailand; see Taylor, 1962), vocal sac absent; head length equal to head width; finger II finger I; no outer metatarsal tubercle; unpigmented eggs of diameter 2 mm; and fine network of minute glandular folds on dorsum.

Most Chinese species of ranids assigned to the genus *Micrixalus* are known from small series: even for the relatively more abundant species, *Micrixalus baluensis*, many of the basic life history information, including larval stages, are unknown (Das, 1995; Inger and Stuebing, 1989). The revision of south-east Asian members of the genus *Micrixalus* sensu lato will therefore require further material (particularly of taxa known from a few examples, such as *M. sariba, M. mariae, M. tenasserimensis* and the three Chinese species allocated to the subgenus *Liurana*). In addition, more complete life history information on these species is needed, and therefore, the generic assignment of *Rana charlesdarwini* here is tentative.

BIOGEOGRAPHY

The amphibian fauna of the Andaman Islands has been reported on by Sarkar (1990) and Pillai (1991), and comprises an admixture of Burmese and endemic elements. Such an assemblage supports the hypothesis of faunal impoverishment since the vicarious separation of the landmasses of continental south-east Asia (at the foot of the Rakhine [Arakan] Yomas, which rises to about 4,000 m above msl) with what now comprises the major island groups within the Andamans Archipelago (Das, 1996; Ripley and Beehler, 1989). As in many other situations within insular south-east Asia, particularly in the Greater Sundas, eustatic sea level rise following the Pleistocene has led to the isolation of a once continental land mass (Gascoyne et al., 1979; Morley and Flenley, 1987), presumably leading to the evolution of endemics on islands separated by the sea. The Rakhine Yomas, which merges into the Himalayas (Krishnan, 1982; Rodolfo, 1969) is considered to be the corridor along which continental south-east Asian, including Himalayan, flora and fauna could have emigrated, to occupy the islands of the Andaman Archipelago, or at least the Great Andamans (comprising the North, Middle and South Andamans). Lowered sea levels associated with the Pleistocene (Chappell and Thom, 1977; Heaney, 1986; 1991) were likely to have connected these islands to the Rakhine hill ranges: sea levels during the maximum Illinoian

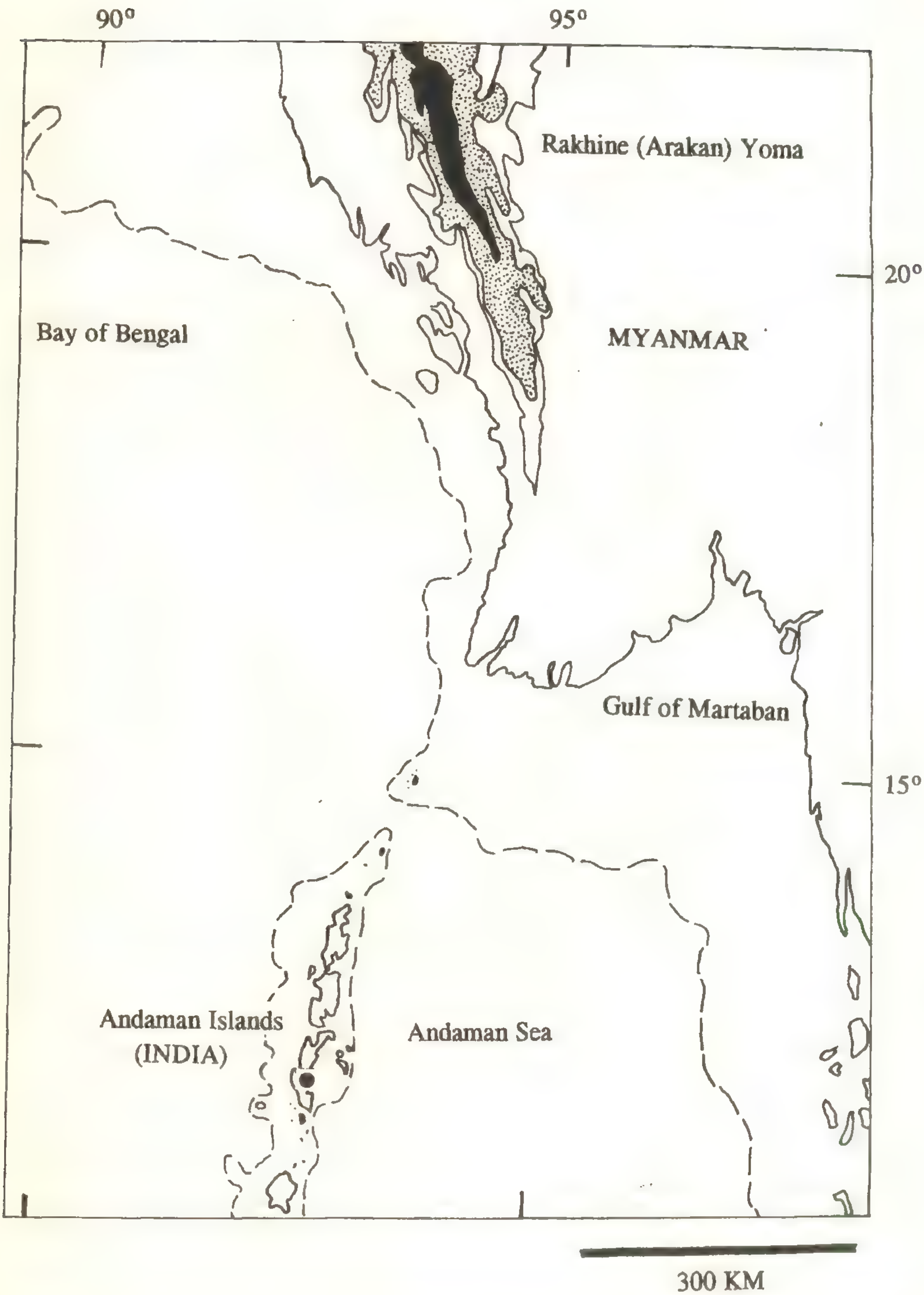

FIGURE 3: Map of south-east Asia, showing coastal and adjacent areas of Myanmar (Burma) and the Andaman Islands (in India), in the Bay of Bengal. The type locality of *Rana charlesdarwini* is indicated with an solid circle. Broken contour off the coast shows the 200 m bathymetric line. The contours of the Rakhine (Arakan) Yomas are defined as follows: unpatterned: 1,000 m; stippled: 2,000 m; and dark: 4,000 m.

(third glacial) being 137.4 or 159.3 m below present levels (Donn et al., 1962).

The Chinese species of *Micrixalus* (that have in the past been referred to variously as *Platymantis* and *Cornufer*) may be the closest relatives of the new species, these reported from China's Yunnan Province and Xizang (Tibet) Autonomous Region. These regions are contiguous (in the north) to the Rakhine Range, and appear to have a similar vegetation (see Plate I in Zhao and Adler, 1993 for a satellite map of the region). In summary, the Arakans may have periodically permitted Indo-Chinese elements to breach to the Andamans, across the formidable barrier of the Gulf of Martaban and the North and South Preparis Channels, during low waters of the Pleistocene. Field collections along the Rakhine Yomas, which have been zoologically poorly investigated, are therefore predicted to yield additional members of this enigmatic assemblage of species, whose identity continue to puzzle systematicists.

ACKNOWLEDGEMENTS

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COMMENTS ON THE SYSTEMATICS OF OLD WORLD *LEPTOTYPHLOPS* (SERPENTES: LEPTOTYPHLOPIDAE), WITH DESCRIPTION OF A NEW SPECIES

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ABSTRACT.– A new long-tailed species of the *Leptotyphlops longicaudus* species group is described from Chad. *Leptotyphlops brevicaudus* is shown to be a synonym of *L. bicolor*. *Leptotyphlops gestri* is reduced to the rank of a subspecies and considered a race of *L. sundewalli* that is probably restricted to Fernando Po Island, Gulf of Guinea. *Leptotyphlops fitzingeri*, *L. variabilis* and *L. macrorhynchus bilmaensis* are considered synonyms of *L. cairi*. *Leptotyphlops debilis* is shown to be a synonym of *L. narirostris boueti*. *Leptotyphlops macrorhynchus algeriensis* (new combination) is recognized from north-western Africa, and *L. hamulirostris* is considered a synonym of *L. m. macrorhynchus*.

KEY WORDS.– *Leptotyphlops adleri*, *algeriensis*, *bicolor*, *bilmaensis*, *boueti*, *brevicaudus*, *cairi*, *debilis*, *fitzingeri*, *gestri*, *hamulirostris*, *macrorhynchus*, *narirostris*, *sundewalli*, *variabilis*, systematics, Africa

INTRODUCTION

The senior author passed on to the junior author a nearly complete manuscript on the Old World Leptotyphlopidae that was last worked on about 1980. In spite of it being nearly 20 years old, both the junior author and D. G. Broadley believed that the merit of the manuscript justified its publication. The original manuscript contained the descriptions of two new species (one of which is described herein) and one new subspecies (recently described as *L. broadleyi* by Wallach and Hahn, 1998). The junior author had been independently studying the same material and will describe the remaining species in a future publication. The examination of types, scale counts, measurements, and taxonomic opinions are all attributable to the senior author; the junior author has merely edited the manuscript deleted certain sections, and updated Table 1. Collaborative work between the junior author and D. G. Broadley on *Leptotyphlops* of East and North Africa has revealed a number of undescribed species and the results of their work supercedes much of the material in the Hahn manuscript. This paper is thus a truncated version of the original manuscript, containing only the proposed taxonomic changes.

The senior author has examined specimens of all but two (*natatrix* and *dissimilis*) African species, including most of the primary type specimens. The original descriptions of these species are poor to only fair, and nearly all lack any numerical meristic data. Subsequent descriptions have not improved the situation greatly, or in some cases are nonexistent. For these reasons the senior author felt it to be desirable to figure and redescribe some of the scarcer, more poorly known species, correct past taxonomic errors, and to describe a new form discovered during the study.

The systematics of the Old World worm snakes of the genus *Leptotyphlops* were in a very primitive state up to 1975. Broadley and Watson (1976) provided an excellent review of most of the species occurring in southern Africa, and Hahn (1978) revised the Asian and Socotra Island species while commenting also on the status of several African forms. *Leptotyphlops perreti* (Roux-Estève, 1979) was described a year later but in the past two decades there has been a hiatus of work on the genus. Research on African *Lep-*

totyphlops has enjoyed a resurgence recently and many species have been described or revalidated (Hallermann and Rödel, 1995; Broadley and Wallach, 1996; 1997a; 1997b; Wallach, 1996; Wallach and Hahn, 1998).

MATERIALS AND METHODS

Unless otherwise identified, terminology and mensural and meristic methods used in this study are identical to those used by Broadley and Watson (1976) and Hahn (1978), with the exception that two abbreviations are used for the previously used ratios L/W (= total length/midbody diameter) and L/TL (= total length/tail length). All L/W ratios are rounded off to nearest whole number. Midbody diameter measurements were made in the horizontal plane. Acronyms follow Leviton et al., 1985.

SPECIES ACCOUNTS

Three specimens from the savanna of southwestern Chad, at the border with Cameroon, represent a distinct, undescribed species of the *Leptotyphlops longicaudus* species group. We take pleasure in naming this snake after Kraig Adler in recognition of his many diverse contributions to the field of herpetology.

Leptotyphlops adleri n. sp.

Fig. 1

Holotype.- MNHN 1978.1910, an adult male from Bongor (10°17'N, 15°22'E), Mayo Kebbi Prefecture, Chad. Collected by Mr. Evrard in 1974.

Paratypes.- MNHN 1978.1911-12, unsexed; same data as for holotype.

Diagnosis.- *Leptotyphlops adleri* is an average-sized, elongate, long-tailed member of the *longicaudus* group, differing from kindred species by having the following combination of major diagnostic characteristics: elongate body form (L/W ratio 87-93), proportionately longer tail (L/TL ratio 7.1-8.7), 41-44 subcaudals, 311-316 middorsals, rostral about 1/2 head width at its widest point, not extending posteriorly to the level of the eyes, slight preoral concavity on inferior surface; anterior supralabial smaller and lower than infranasal, width of anterior supralabial about equal to that of infranasal, less than 1/3 the width of ocular when measured at the lip border; ocular in contact with lip, width approximately equal to that of supranasal; eyes clearly visible beneath superior portion of ocular; single posterior supralabial following ocular, which almost reaches the height of the eye; parietals and occipitals undivided, parietals distinctly wider than occipitals; cutaneous touch corpuscles sparse, restricted to anterior portion of head; mental absent.

Description of holotype.-Total length 135 mm, tail length 19 mm, middorsals 311, 14 scale rows around midbody, subcaudals 44, 10 scale rows around middle of tail, which is stout for its entire length, tapering abruptly to a short terminal spine; body and tail roughly cylindrical, horizontal diameter slightly greater than vertical diameter; anal plate distinctly larger than surrounding scales; L/TL ratio 7.1, L/W ratio 93; left hemipenis partially everted.

Middorsal five scale rows pigmented light brown at midbody, vertebral row darkest; anterior portion of body lightest brown, gradually darkening posteriorly; venter cream, with no clear line of demarcation between dorsal and ventral pigmentation.

Variation in the paratypes.- MNHN 1978.1911 measures 122 mm total length, 14 mm tail length, middorsals number 316, subcaudals 41, L/TL ratio 8.7, and L/W ratio 87. The caudal portion of MNHN 1978.1912 is damaged anterior to the vent, and the tail is missing. The head scutellation of both paratypes is consistent with that described for the holotype.

Range.- Known only from the type locality of Bongor, Chad.

Specimens examined.- MNHN 1978.1910 (holotype) and MNHN 1978.1911-12 (paratypes).

Leptotyphlops narirostris (Peters)

1867 *Stenostoma narirostre* Peters, *Mber. Konig. preuss. Akad. Wiss. Berlin* 1867: 708. Type locality: Lagos, Nigeria. Holotype: ZMB 5915.

Content.- Two subspecies are currently recognized.

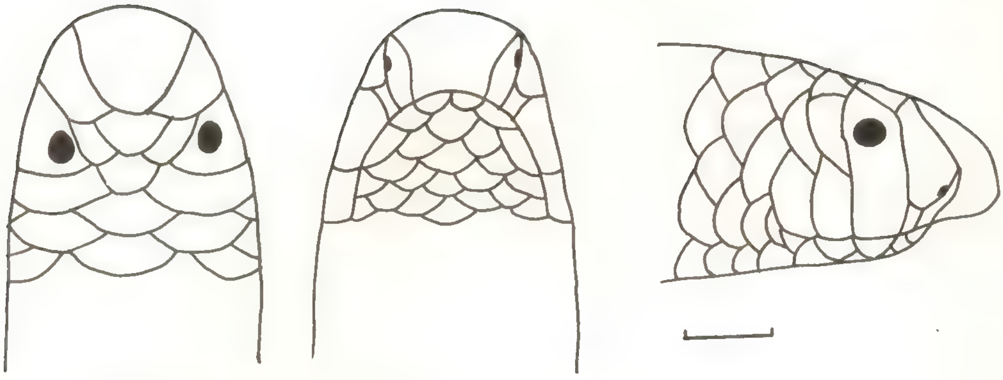

FIGURE 1: Dorsal, ventral and lateral views of the head of *Leptotyphlops adleri* n. sp.

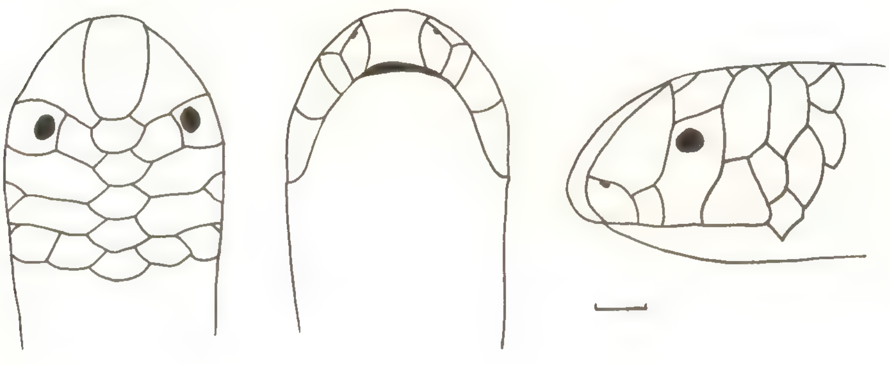

FIGURE 2: Dorsal, ventral and lateral views of the head of *Leptotyphlops n. narirostris.*

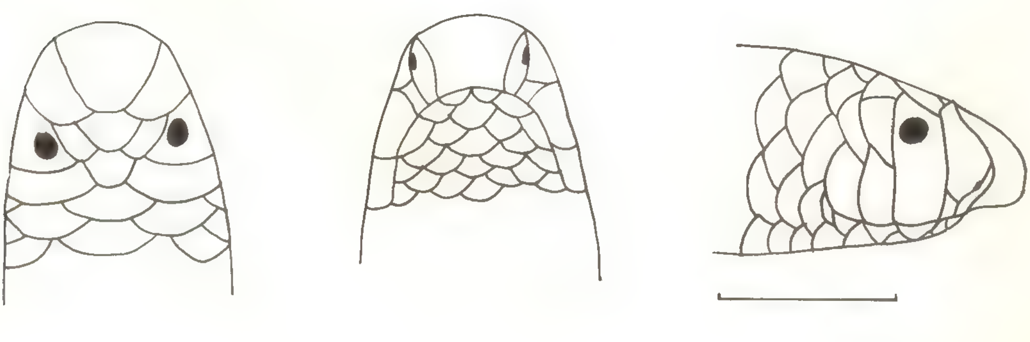

FIGURE 3: Dorsal, ventral and lateral views of the head of *Leptotyphlops n. boueti.*

Leptotyphlops narirostris narirostris (Peters)
Fig. 2

Diagnosis.– The nominate subspecies is characterized by having a snout rounded in lateral view with no preoral concavity on the inferior rostral; rostral extends posteriorly to the level of the eyes; total middorsals number 208-295 (mean 248.3); body stout with L/W ratio 27-64 (mean 39); L/TL ratio 5.3-11.4 (mean 8.8); maximum length = 230 mm.

Leptotyphlops narirostris boueti (Chabanaud)
Fig. 3

1917 *Glauconia boueti* Chabanaud, *Bull. Mus. Natn. Hist. Nat., Paris* 23: 9, figs. Type locality: "Soudan" (= Djenné, Mali). Holotype: MNHN 1917.24.

1918 *Glauconia debilis* Chabanaud, *Bull. Mus. Natn. Hist. Nat., Paris* 24: 111. Type locality: "Kousri, Cameroon" (= Koussri). Holotype: MNHN 1904.180.

1950 *Leptotyphlops narirostris boueti* - Villiers, Les serpents de l'Ouest Africain: 55.

1980 *Leptotyphlops debilis* - Hahn, *Das Tierreich* 101: 11.

1980 *Leptotyphlops narirostris boueti* - Hahn, *Das Tierreich* 101: 22.

Diagnosis.– Differs from the nominal race in the following characteristics: a preoral concavity on the inferior rostral, giving the snout a weak hook in lateral view; rostral usually does not reach posteriorly to the level of the eyes; a higher number of total middorsals 288-319 (mean 302.5); a slightly shorter tail, the L/TL ratio 10.4-14.2 (mean 11.9); a more elongate body form, the L/W ratio 55-105 (mean 78); smaller size with maximum length 179 mm.

Range.- Mauritania, Sénégal, Mali and Chad.

Remarks.- *Leptotyphlops n. boueti* has been considered a geographical race of *L. narirostris* since Villiers (1950a) used the name combination based upon the opinion of A. Loveridge. A case could be made for considering *L. n. boueti* a distinct species. The senior author has not examined any specimens considered to be intergrades, and the two forms vary in several significant characteristics.

In 1918, Chabanaud described *Glauconia debilis* from Koussri, Chad, and considered it related to *G. distanti*, *G. narirostris* and *G. reticulatus*, with which brief comparisons were made. A reexamination of the holotype (MNHN 1904.180) of this long-ignored species reveals it to be indistinguishable from *L. n. boueti*. The specimen is in good condition and measures 110 mm in total length, has a tail length of 9 mm, and a midbody diameter of 2.0 mm. Total middorsals number 296 and subcaudals 31, L/W ratio 61, and L/TL ratio 12.2. There are 10 scale rows around the middle of the tail.

Specimens examined (11).– CHAD: Fort Lamy, MNHN F5 & F7; Koussri, MNHN 1904.180 (holotype of *G. debilis*); Maillao (120 km S Fort Lamy), MNHN F74; MALI: "Soudan", MNHN 1917.24 (holotype of *G. boueti*); SÉNÉGAL: Gorée, MNHN 9894-96; Youpé, MHNH 1918.163; Longa, MNHN 1938.262; Cape Verd, vicinity of Dakar, CM 24699.

Leptotyphlops macrorhynchus (Jan)

1860 *Stenostoma* (*Ramphostoma*) *macrorhynchum* Jan, Icon. Gen. Ophid.: 1: 1 livr., pl. 5 & 6, fig. 12. Type locality: Sennaar, Sudan. Holotype: formerly MSNM, now destroyed.

Range.– West Africa eastward across North Africa, the Middle East, and southwest Asia to northwestern India, and north to Turkey. There is a hiatus in the range in the Nile River Valley region. In Africa, this species has been recorded from Morocco, Mauritania, Algeria, Tunisia, Mali, Guinea, Ghana, Libya, Niger, Nigeria, Chad, Egypt, Sudan, Ethiopia and Kenya. Material from areas of sympatry with *L. n. boueti* (Guinea, Ghana, Nigeria, etc.) needs to be reexamined to ensure correct identification.

Content.– Two geographical races are here recognized.

Leptotyphlops macrorhynchus macrorhynchus (Jan)
Fig. 4

1890 *Glauconia macrorhynchus* - Boulenger, *Ann. Mag. nat. Hist.* 6 (6): 92.

1907 *Glauconia hamulirostris* Nikolsky, *Ann. Mus. Zool. Acad. Imp. Sci. St. Petersbourg*,

10: 260. Type locality: Aguljaschker, 49°40'E, 31°40'N, Iran. Lectotype: ZIL N10299, 305.

1914 *Leptotyphlops phillipsi* Barbour, *Proc. New England Zool. Club* 5: 87, fig. Type locality: Petra, Arabia (= Jordan). Holotype: MCZ 9650.

1929 *Glauconia erythraea* Scortecci, *Atti Soc. Ital. Sci. nat., Milano* 67 (3-4): 293, fig. Type locality: Massaua, Eritrea. Holotype: MSNM 1916.

1929 *Glauconia braccianii* Scortecci, *Atti Soc. Ital. Sci. Nat., Milano* 67 (3-4): 294, fig. Type locality: Adi Ugri, Eritrea. Holotype: MSNM 1917.

1932 *Leptotyphlops macrorhynchus* - Corkill, Snakes and snake bite in Iran & Iraq: 8.

1949 *Leptotyphlops erythraea* - Parker, *Zool. Verh., Leiden* (6): 21.

1949 *Leptotyphlops braccianii* - Parker, *Zool. Verh., Leiden* (6): 21.

1956 *Leptotyphlops hamulirostris* - Mertens, *Jh. Ver. vaterl. Naturk. Württemb.* 111 (1): 90.

1980 *Leptotyphlops braccianii* - Hahn, *Das Tierreich* 101: 9.

1980 *Leptotyphlops erythraeus* - Hahn, *Das Tierreich* 101: 14.

1980 *Leptotyphlops hamulirostris* - Hahn, *Das Tierreich* 101: 16.

1980 *Leptotyphlops macrorhynchus macrorhynchus* Hahn, *Das Tierreich* 101: 20.

Diagnosis.- The nominate subspecies is characterized by having total middorsals numbering 297-492 (mean 378.1); subcaudals 26-53 (mean 38.9); L/W ratio 49-143 (mean 63); L/TL ratio 7.5-15.6 (mean 11.7).

Range.- Same as for the species with the exception of north-western Africa, where it is replaced by *L. m. algeriensis*.

Remarks.- Kramer and Schnurrenberger (1963) figured and redescribed *L. hamulirostris* (Nikolsky) from south-eastern Iran using the type series, and compared them with a western Egyptian specimen of *L. macrorhynchus* (= *L. cairi* fide D. G. Broadley, in. litt.). Although they did not compare *hamulirostris* with neighbouring Asian populations of *L. macrorhynchus*, they concluded that they were probably dealing with two distinct species. Following Kramer and Schnurrenberger (1963), Hahn (1978) also recognized *L. hamulirostris*, but noted difficulty in distinguishing it from other Asian specimens of *L. macrorhynchus* using their data and head figures. Unfortunately, no direct comparison of specimens was then possible. The senior author is grateful to Dr. Alan E. Leviton (CAS) for calling his attention to two syntypes of *Glauconia hamulirostris* in the CAS collection. These specimens, CAS 99737-38 (original number ZIL 10299), from Aguljaschker, Arabistan (= Khusistan), Iran, are indistinguishable from adjoining Asian populations of *L. m. macrorhynchus*. A comparison of the data taken from the type series of *G. hamulirostris* with those of other Asian populations of *L. m. macrorhynchus* shows agreement in all meristic and proportional characteristics: total middorsals 351-389 (mean 370.0) in *hamulirostris* and 324-492 (mean 399.7) in Asian *macrorhynchus*; subcaudals, 35-46 (mean 40.5) compared to 33-48 (mean 40.7); L/TL ratio 10.1-13.5 compared to 10.0-14.7; and L/W ratio 76-81 in *hamulirostris* and 57-143 in *macrorhynchus*. There also appear to be no consistent differences in head lepidosis. The senior author has no doubt that *Glauconia hamulirostris* belongs in the synonymy of *L. m. macrorhynchus*.

The figures given for the L/TL character and the ranges of total middorsals given in Hahn's (1978) text description of *L. hamulirostris* were in error. The correct ranges were, however, presented in his Table 1. Total middorsals in females are 382-389 (mean 386) whereas in males the range is 351-371 (mean 362).

Specimens examined (in addition to those listed by Hahn, 1978).- TURKEY: 5 km E Birecik, 2000 ft., CAS 105400; 30 km E Urfa, CAS 105426; 30 km W Kiziltepe, 2000 ft., CAS 105926, 105928-31; IRAN: Aguljaschker, Arabistan (= Khusistan), CAS 99737-38 (syntypes of *Glauconia hamulirostris*).

Leptotyphlops macrorhynchus algeriensis (Jacquet)

1896 *Glauconia algeriensis* Jacquet, *Bibliog. Anat.* 4: 79-81, figs. 1-3. Type locality:

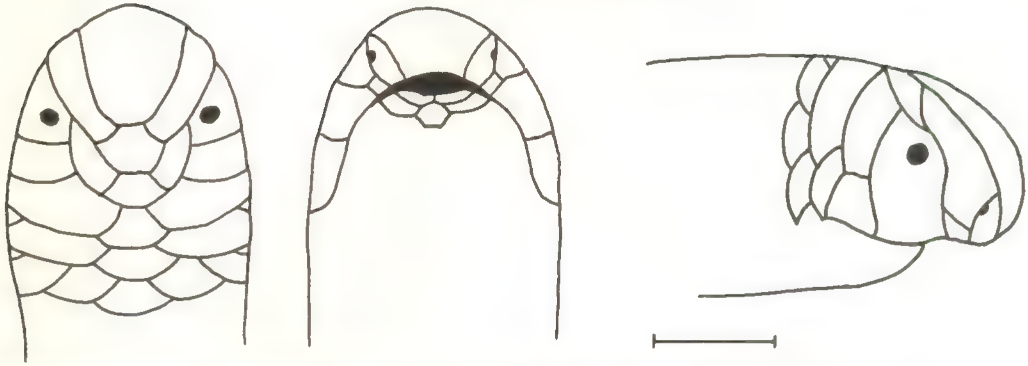

FIGURE 4: Dorsal, ventral and lateral views of the head of *Leptotyphlops m. macrorhynchus.*

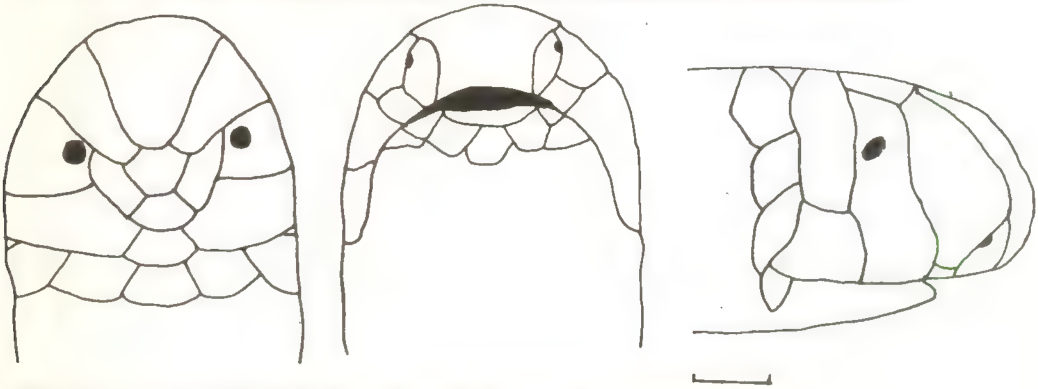

FIGURE 5: Dorsal, ventral and lateral views of the head of *Leptotyphlops cairi.*

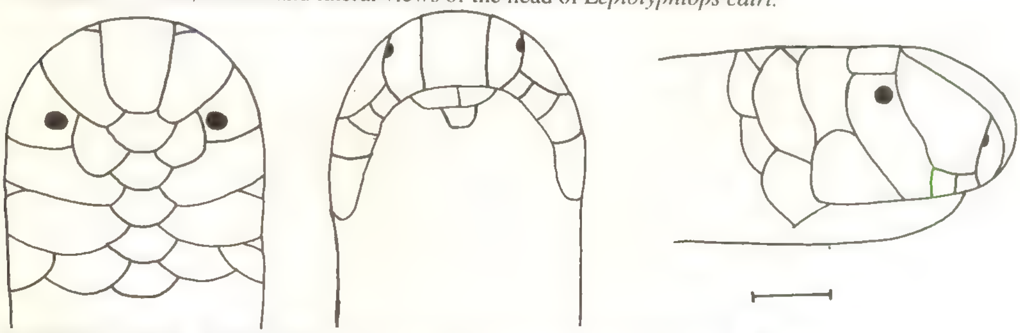

FIGURE 6: Dorsal, ventral and lateral views of the head of *Leptotyphlops b. bicolor.*

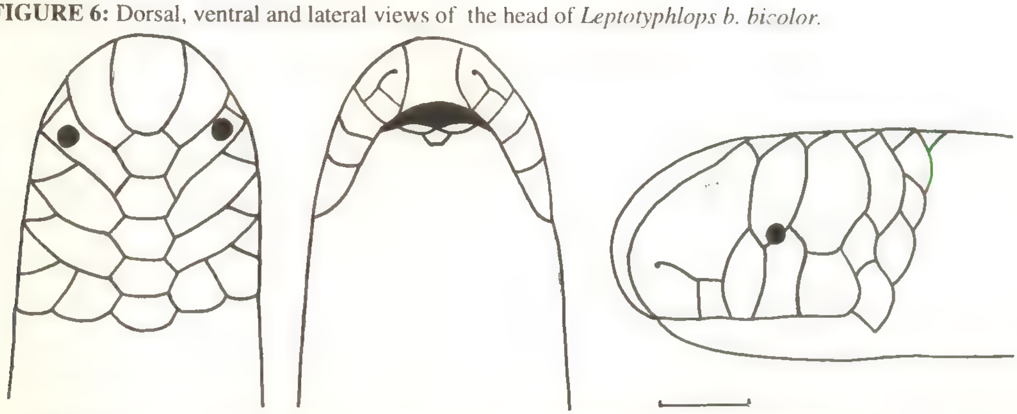

FIGURE 7: Dorsal, ventral and lateral views of the head of *Leptotyphlops s. sundewalli.*

Hammam Salahine, 6 km north of Biskra, Algeria. Holotype: not traced, possibly in the Institute of Anatomy, Bucharest.

1980 *Leptotyphlops macrorhynchus macrorhynchus* - Hahn, *Das Tierreich* 101: 20.

Diagnosis.– This race is distinguished from the nominal race by having a much higher middorsal count (528-558 [mean 545.7] compared to 307-329 [mean 316.3] for other African specimens); slightly higher number of subcaudals (45-47 [mean 46.3] vs. 26-42 [mean 35.0] for others); a proportionately shorter tail (L/TL ratio 14.1-17.5 [mean 15.6] vs. 7.9-13.7 [mean 10.8] for other African specimens); and a more elongate body form (L/W ratio 99-138 [mean 114] vs. 49-66 [mean 57] for others). Largest specimen examined measured 287 mm. Asian populations overlap in some characteristics (see Table 1), but none have as great a number of middorsals.

Range.– Western Sahara in Algeria, Morocco, Tunisia, eastern Mali, and north-western Niger.

Remarks.– Examination of four Algerian specimens of *Leptotyphlops macrorhynchus* shows that they vary significantly from other African and Asian populations of this species, and are worthy of subspecific recognition. A name is available for this geographic race based upon a specimen from the Algerian Sahara, *Glauconia algeriensis* Jacquet (1896). Jacquet consulted with Boettger before describing his specimen from near Biska, and obtained the opinion that it was allied to *G. macrorhynchus*. Because Jacquet's description of *G. algeriensis* did not adequately distinguish it from *macrorhynchus*, Anderson (1898) and Boulenger (1920b) considered it a synonym of *G. macrorhynchus*. They obviously did not pay much attention to the illustrations, which depict a very different animal from *macrorhynchus*.

Specimens examined (4).– ALGERIA: Beni Abbes, MNHN 8648 & 8648A; Oued Tahouilet, NW of Djanet, MNHN 1951.328; MALI: east of Bourem, CAS 84215.

Leptotyphlops cairi
(Duméril & Bibron)
Fig. 5

1844 *Stenostoma cairi* Duméril and Bibron, Erpét. Gén. 6: 323. Type locality: Cairo, Egypt. Holotype: MNHN 3231.

1861 *Stenostoma fitzingeri* Jan, *Arch. Zool. Anat. Fisiol.* 1: 189. Type locality: "Ile de Rhodes," corrected by Anderson (1898) to Isle of Rhodes in Nile River, near Cairo, Egypt. Holotype: MSNM.

1890 *Glauconia cairi* - Boulenger, *Ann. Mag. Nat. Hist.* (6) 6: 92.

1893 *Glauconia fitzingeri* - Boulenger, Cat. Snakes Brit. Mus. (Nat. Hist.) 1: 66.

1928 *Glauconia variabilis* Scortecci, *Atti Soc. Ital. Sci. Nat., Milano* 67: 290. Type locality: Adi Ugri, Eritrea. Holotype: MSNM.

1932 *Leptotyphlops cairi* - Parker, *Proc. Zool. Soc. London* 1932: 362.

1936 *Leptotyphlops macrorhynchus bilmaensis* Angel, *Bull. Soc. Zool. France* 61: 274. Type locality: Oasis of Bilma, Niger. Syntypes: MNHN 1936.99-102.

1949 *Leptotyphlops variabilis* - Parker, *Zool. Verh. Leiden* (6): 21.

1980 *Leptotyphlops cairi* - Hahn, *Das Tierreich* 101: 10.

1980 *Leptotyphlops fitzingeri* - Hahn, *Das Tierreich* 101: 14.

1980 *Leptotyphlops macrorhynchus bilmaensis* - Hahn, *Das Tierreich* 101: 20.

1980 *Leptotyphlops variabilis* - Hahn, *Das Tierreich* 101: 28.

Diagnosis.- Head wider than neck and slightly depressed, snout rounded in lateral view; dorsal rostral one-half the width of head, extending posteriorly to the level of the eyes, with weak preoral concavity on inferior rostral; postfrontal longitudinally divided in 10% (3/32) of specimens examined; occipitals divided in 78% of material examined; single mental present in 1/3 of specimens, touching anterior lip margin.

Range.- Northern Africa, including Mauritania, Niger, Chad, Egypt, Sudan, Eritrea, Ethiopia, and Somalia.

Remarks.- Jan and Sordelli (1860), Boulenger (1893), Anderson (1898), Werner (1917), and Gans and Laurent (1965) all figure or report a

semidivided nasal in *L. cairi*, and most have used this character in keys to distinguish *cairi* from other round-snouted species with completely divided nasals. In the senior author's examination of 31 *L. cairi* from throughout its range, plus the junior author's examination of six specimens from Egypt, we failed to find a single specimen with a semidivided nasal. We attribute this discrepancy to the difficulty in discerning sutures between the highly polished, smooth, close-fitting scales, the poor optics of the last century, and probably the acceptance by later workers of Jan and Sordelli's (1860) figure as accurately depicting the condition of the nasals without a close re-examination.

Jan (1861) described *Stenostoma fitzingeri* from "Ile de Rhodes," and Jan and Sordelli (1860) figured the species. Anderson (1898) considered *S. fitzingeri* to be closely related to *Glauconia cairi* and suggested that the actual type locality of *fitzingeri* was Rhodes Island in the Nile River near Cairo, Egypt. No snakes of this genus are known from the larger island of Rhodes at the entrance to the Aegean Sea. Werner (1917) attributed the synonymizing of *fitzingeri* with *cairi* to Anderson (1898). While this is not true, a comparison of Jan and Sordelli's (1860) figures of *S. fitzingeri* with *L. cairi* leads the senior author to suspect that they are indeed conspecific. The figure of *S. fitzingeri* differs from typical *L. cairi* in having a larger anterior supralabial, a smaller posterior supralabial, and a semidivided nasal. *Leptotyphlops cairi* exhibits some variation in the size of the anterior supralabial, occasionally approaching that depicted by Jan and Sordelli (1860) in their figure of *S. fitzingeri*. However, in no specimen of *L. cairi* examined is the posterior supralabial as small as that figured by Jan and Sordelli. It is easy to discount the condition of the nasal as a similar error was made in the figure of *S. cairi* discussed above. Many of Jan and Sordelli's (1860) figures of the smaller scolecophidians are inaccurately drawn (cf. Amaral, 1926). For instance, with but one exception, all of their 15 figures of *Stenostoma* (= *Leptotyphlops*) species have a single median mental bordering the margin of the lower lip, yet this character is rarely found in Old World members of the genus. In the normal condition, the first pair of infralabials meet anteriorly on the midline, separating the mental from the lip margin. Orejas-Miranda (1967) and Orejas-Miranda et al. (1977) considered these scales to be a divided mental, while Hoogmoed (1977) considered the azygous median scale just posterior of the first infralabials to be the true mental.

Scortecci (1928) described and figured a round-snouted species, *Glauconia variabilis*, based upon three specimens from Eritrea. While he compared his new species to be closely related to *G. macrorhynchus*, a hook-snouted form, and *G. bracciani* (a synonym of *L. macrorhynchus*), Scortecci did not compare it with the sympatric, round-snouted *G. cairi*. Parker (1949) commented that *L. variabilis* may not be specifically distinct from *L. cairi*. As Scortecci's (1928) figures and description are indistinguishable from our data on *L. cairi*, we also consider *G. variabilis* to be a synonym of *L. cairi*.

Only one geographical race of *L. macrorhynchus*, *L. m. bilmaensis* from the Bilma Oasis of Niger, has been described. Villiers (1952; 1975) considered this race to be indistinguishable from other West African specimens of *L. macrorhynchus* and reduced it to the synonymy of *L. macrorhynchus*. The senior author's examination of the type series (MNHN 1936.99-102) of *L. m. bilmaensis* reveals that they are indistinguishable from typical *L. cairi*. Middorsals range from 334-363 (mean 353) and subcaudals number 31-34 (mean 32.3). This startling discovery is unexpected as the range of *L. cairi* has previously been considered restricted to the greater Nile River area, and these specimens represent a trans-continental range extension. Also supporting this allocation is another specimen (BMNH 1913.5.9.45) of *L. cairi* from Traiza Country, Mauritania, collected by Audain prior to 1914. This specimen has 314 middorsals, 32 subcaudals, L/TL ratio 11.9, and L/W ratio 90.

Specimens examined (32).- EGYPT: no specific locality, BMNH 1938.8.4.50; MNHN 1909.185-86; Giza, W. Cairo, BMNH 1909.3.25.5-6; Cairo, MNHN 3231 (holotype); Rhoda Island, near Cairo, BMNH 1897.10.28.523; Luxor, BMNH 1897.10.28.524-25; Thebes, BMNH 1865.6.12.23; Ghijeh, BMNH 1900.2.8.5-6,

1903.6.18.2-11; MAURITANIA: Traiza Country, BMNH 1913.5.9.45; NIGER: Bilma Oasis, MNHN 1936.99-102 (syntypes of *Leptotyphlops macrorhynchus bilmaensis*); SOMALIA: Wagga Goolis Mtns., near Berkera, 3000-4000 ft., BMNH 1905.11.7.40-41; Daggal Bur, BMNH 1949.2.3.47; 10°10'N, 42°05'E, 4000 ft., BMNH 1949.2.3.48; SUDAN: White Nile, Gabl el Magatuir, BMNH 1900.9.22.23; Durrui, north of Sawakin, BMNH 1897.10.28.537.

Leptotyphlops bicolor (Jan)
Fig. 6

1860 *Stenostoma* (*Tricheilostoma*) *bicolor* Jan in: Jan and Sordelli, Icon. gén. Ophid., livr. 1, pl. 5, fig. 15. Type locality: Boutry, Gold Coast (=Butre, Ghana). Syntypes (2): RMNH 3683.

1860 *Stenostoma* (*Tricheilostoma*) *gracile* Jan in: Jan and Sordelli, Icon. gén. Ophid., livr. 1, pl. 5, fig. 14, pl. 6, fig. 14. Type locality: not given. Holotype: RMNH 3683. Synonymy fide Jan, 1864: 40.

1887 *Stenostoma brevicauda* Bocage, *J. Sci. Math. Phys. Nat., Lisboa* 11: 194, Type locality: Dahomey (= Benin). Holotype: MBL, now destroyed by fire.

1890 *Glauconia brevicauda* - Boulenger, *Ann. Mag. Nat. Hist. (6) 6: 92.*

1890 *Glauconia bicolor* - Boulenger, *Ann. Mag. Nat. Hist. (6) 6: 92.*

1917 *Glauconia bicolor gruveli* Chabanaud, *Bull. Mus. Hist. Nat., Paris* (1916) 22: 367. Type locality: Dahomey (= Benin). Holotype: MNHN 1916.196. Synonymy fide Villiers, 1950a: 23.

1920a *Glauconia gruveli* - Boulenger, *Proc. Zool. Soc. London* 1919: 267.

1933 *Leptotyphlops bicolor* - Angel, *Bull. Com. Étud. Hist. Sci. l'A.O.F.* (1932), 15: 667.

1933 *Leptotyphlops brevicauda* - Angel, *Bull. Com. Étud. Hist. Sci. l'A.O.F.* (1932), 15: 55.

1950b *Leptotyphlops bicolor gruveli* - Villiers, Les serpents de l'Ouest Africain: 58.

1980 *Leptotyphlops cairi* - Hahn, *Das Tierreich* 101: 7.

1980 *Leptotyphlops brevicaudus* - Hahn, *Das Tierreich* 101: 9.

Diagnosis.- A small *Leptotyphlops* species having a rounded snout; two (occasionally one) anterior supralabials between the infranasal and ocular; prefrontal present; rostral not in contact with supraoculars; supraoculars about equal in size to prefrontal and frontal; occipitals usually undivided, only rarely divided on both sides; total middorsals less than 290; subcaudals less than 17; 12 scale rows around the middle of the tail, which is more or less round in cross-section.

Range.- Southern Mali, Burkina Faso, Ghana, Togo, Benin, Nigeria, south-western Niger and south-western Chad.

Remarks.- During examination of four specimens of the rare *L. brevicaudus* (Bocage), it was noted that they were identical to *L. bicolor* in body and tail proportions, colouration and meristic data. In addition, a review of the literature shows the ranges of *L. brevicaudus* and *L. bicolor* are sympatric, both species having been recorded from Mali, Burkina Faso, Cote d'Ivoire, Ghana, Benin and Nigeria. Head scutellation is also identical in both species with the single exception of the number of anterior supralabials between the infranasal and ocular. In *L. brevicaudus*, a single somewhat broad anterior supralabial is present, its posterior border higher than its anterior one. In *L. bicolor*, two narrow anterior supralabials are present, divided by a vertical suture, that together present the same size and configuration as the single shield in *L. brevicaudus.* Data for the *L. brevicaudus* examined includes total middorsals 261-265, subcaudals 10-14, 12 midtail scale rows, L/TL ratio 23.0-30.8, L/W ratio 41-58, occipitals undivided, and the maximum length 175 mm. See Table 1 for a comparison with *L. bicolor*. Additionally, one Burkina Faso specimen (MNHN 1965.95A), three Cote d'Ivoire specimens (MNHN 1977.94, 1977.102-03), and seven Ghana specimens (BMNH 1927.8.31.1; BH L1B 396, 406, 409-11, 428) are intermediate between *L. brevicaudus* and *L. bicolor* in having two anterior supralabials on one side of the head but only one on the opposite side. In view of the overall similarities and identical ranges, the two taxa are believed to be conspecific, with the undivided anterior supralabials ("*brevicaudus*") being an occasional variant occurring throughout the range of *L. bicolor*, and *L.*

brevicaudus is placed in the synonymy of *L. bicolor*.

Glauconia bicolor gruveli Chabanaud is based on a single specimen (MNHN 1916.196) from "Dahomey" that was distinguished from the typical race by being more elongate (L/W ratio 78) and having a shorter tail (L/TL ratio 36.8). Boulenger (1920a) considered *G. gruveli* a distinct species, and pointed out that in the original description Chabanaud erroneously gave the tail length as the diameter. Villiers (1950a; 1950b) again relegated *gruveli* to a race of *L. bicolor*, and Villiers (1952) then synonymized it with *L. bicolor*. The senior author re-examined the holotype of *G. b. gruveli* and found it to be a typical representative of *L. bicolor*. The specimen is in fair condition, having lost much of its body scalation, and is somewhat flattened and kinked. It has the following measurements: total length 154 mm, tail length 5.5 mm, midbody diameter 3.3 mm, middorsals 269, subcaudals 12, and midtail scale rows 12. In contrast to Chabanaud (1917), the L/W ratio is 47 and the L/TL ratio 28.0. The cephalic scutellation is identical to that of other *L. bicolor*. Four other Benin specimens of *L. bicolor* examined have L/W ratios from 41-48 (mean 44) and L/TL ratios from 28.3-34.4 (mean 30.5), which are similar to range-wide data obtained from 39 other specimens of *L. bicolor* (see Table 1). The middorsal counts (260-268, mean 263.0) and subcaudal counts (10-12, mean 11.5) for the Benin specimens are also near the mean for *L. bicolor*.

Specimens examined (39).- BENIN: no specific locality, MNHN 1916.196 (holotype of *Glauconia bicolor gruveli*); Porto Novo, MNHN 1917.176-176A; Ouidat, MNHN 1916.119-119A; GHANA: no specific locality, BMNH 1927.9.27.166; Accra, BMNH 1930.3.4.1-2, 1920.4.28.1; SMF 16706; Achimota, L1B 406-07; BMNH 1927.8.31.1; CM 54737, 90387-88; Legon, BH L1B 396, 409, 428; South Ashanti, Obuasi, BMNH 1917.4.13.5; MALI: Sikasso, MNHN 1965.94; NIGER: Niamey, AMNH 115860; Tapoa, AMNH 115861-63; NIGERIA: Kwara State, New Bussa, BMNH 1970.1773; Enugu, BMNH 1959.1.2.41; Samaru, BMNH 1975.576; Zaria Prov., Nigerian Tobacco Co. estate, BMNH 1961.2090; Northwest State, Yelwa, BMNH 1970.1774; BURKINA FASO: no specific locality, MNHN 1908.167; Garango, MNHN 1965.95-95A, 1965.97-97A; Ouagadouga, MNHN 1933.151-53.

Leptotyphlops sundewalli (Jan)

1861 *Stenostoma* (*Tricheilostoma*) *sundewalli* Jan, *Arch. Zool. Anat. Fisiol.* 1: 191, and Jan and Sordelli, 1861, Icon. Gen. Ophid., livr. 2, pl. 5, fig. 11. Type locality: "West Africa." Holotype in MSNM.

1890 *Leptotyphlops sundevalli* Boulenger (emendation), *Ann. Mag. nat. Hist. (6) 6: 92*.

1950 *Leptotyphlops sundevalli* - Villiers, Les serpents de l'Ouest Africain: 55.

1980 *Leptotyphlops sundewalli* - Hahn, *Das Tierreich* 101: 27.

Diagnosis.- A species of *Leptotyphlops* characterized by having two anterior supralabials, 12 scale rows around the middle of the tail, supraocular in contact with anterior supralabial, eye reduced to a dark spot lacking a discernible pupil, and an incompletely divided nasal.

Content.- Two subspecies are recognized.

Leptotyphlops sundewalli sundewalli (Jan)
Fig. 7

Diagnosis.– The nominate subspecies is characterized by lacking the nostril-rostral suture and having the occipitals usually divided; total middorsals number 202-286 (mean 260.3); L/W ratio 35-63 (mean 43); L/TL ratio 17.5-45.0 (mean 24.2); maximum length = 144 mm.

Leptotyphlops sundewalli gestri (Boulenger), new combination

1906 *Glauconia gestri* Boulenger, *Ann. Mus. Civ. Stor. Nat. G. Doria, Genova* 2: 210. Type locality: Musola and Basile, Fernando Po Island, and Buea, Cameroon. Lectotype here designated as BMNH 1946.1.17.3 from Basile, Fernando Po.

1961 *Leptotyphlops gestri* - Perret, *Bull. Soc. Neuchâtel. Sci. Nat.* (3) 84: 133.

1980 *Leptotyphlops gestri* - Hahn, *Das Tierreich* 101: 14.

A direct comparison of the BMNH syntype of *Leptotyphlops gestri* with specimens of *L. sundewalli* reveals them to be identical in nearly all

TABLE 1: Meristic data for adult Old World *Leptotyphlops* species. n = sample size; TMD = total middorsals (mean, sample size); SC = subcaudals; L/TL = total length divided by tail length; L/W = total length divided by midbody horizontal diameter; TR = midtail scale rows; ML = maximum length in mm; OC = usual condition of occipital shield (D = divided, E = entire). Data or bulk of data from Bocage (1886), Werner (1917), Andersson (1937), Broadley and Watson (1976), Hahn (1978a), Roux-Estève (1979), Gasperetti (1988), Hallermann and Rödel (1995), Broadley and Wallach (1996, 1997a-b), Wallach (1996), Wallach and Hahn (1998) and Broadley and Broadley (in prep.).

Species	n	TMD	SC	L/TL	L/W	TR	ML	OC
adleri n. sp.	3	313.5 (311-316)	41-44	7.1-8.7	87-93	10	135	E
albiventer	5	190.0 (165-230)	26-31	6.1-8.8	41.51	10	128	E
bicolor	58	262.3 (247-288)	9-16	23.0-36.8	31-69	12	184	E
blanfordii	11	323.8 (312-338)	27-38	10.5-15.1	46-67	12	242	E
boulengeri	5	184.4 (179-192)	18-21	10.3-12.7	30-37	10	203	E
broadleyi	12	186.3 (173-193)	13-16	14.3-19.6	24-44	12	112	E
burii	2	405.5 (403-408)	28-33	14.2-14.4	57-59	12	210	D
cairi	30	339.9 (267-370)	27-36	10.9-16.1	46-94	10	254	D
conjunctus	62	217.0 (183-238)	19-27	8.6-13.7	42-71	10	180	E
c. incognitus	210	253.0 (230-292)	25-35	7.9-12.8	47-106	10	193	E
c. latrirostris	2	209.0 (206-212)	24-25	10.7-13.0	44-58	12	155	E
dissimilis	–	–	29-30	11.5	42	–	104	–
distanti	93	269.0 (239-307)	19-30	10.6-18.6	49-106	12	235	D
drewesi	1	248	26	11.9	41	10	143	E
emini	86	230.7 (188-263)	19-29	9.8-15.5	40-76	10	177	E
filiformis	2	483.0 (479-487)	46-48	10.5-11.7	76-100	10	155	D
gracilior	24	329.9 (305-362)	24-41	9.3-18.8	69-111	10	240	E
labialis	26	306.3 (287-338)	18-24	14.3-24.5	54-106	12	279	E
longicaudus	78	239.0 (266-325)	34-58	5.7-11.0	49-90	10	245	E
macrops	7	293.4 (272-313)	30-40	8.6-12.3	53-73	10	292	E
macrorhynchus	62	378.1 (297-492)	26-53	7.5-15.6	49-143	10	293	E
m. algeriensis	4	533.3 (496-558)	41-47	14.1-17.5	99-138	10	287	E
macrurus	9	268.9 (257-277)	43-54	5.4-6.5	36-45	10	170	D
narirostris	16	248.3 (208-295)	25-43	5.3-11.4	27-64	10	230	E
n. boueti	22	302.5 (288-319)	31-34	10.4-14.2	55-105	10	179	E
natatrix	1	–	–	10.1	61	–	135	–
nigricans	71	234.0 (212-289)	20-34	7.6-16.6	38-77	10	199	E
nursii	13	333.8 (281-378)	32-48	10.0-16.8	48-101	12	242	E
occidentalis	75	319.7 (276-351)	21-30	13.2-23.3	64-142	12	322	E
pembae	6	254.5 (247-269)	20-36	7.2-10.8	54-68	10	201	E
perreti	3	294.0 (286-302)	49-55	5.9-7.5	44-74	10	284	E
pungwensis	1	252	21	15.0	70	10	90	E
reticulatus	2	232.0 (227-237)	28-32	9.2-12.5	41-57	10	200	E
rostratus	6	273.2 (241-287)	20-23	12.8-16.9	45-64	12	192	E
scutifrons	340	263.0 (197-307)	19-30	9.3-19.6	48-89	10	278	E
s. merkeri	45	244.2 (200-272)	19-29	7.9-18.5	40-89	12	188	E
sundewalli	33	260.3 (202-286)	7-14	17.5-45.0	33-63	12	144	E
s. gestri	1	202	12	17.5	38	12	96	E
sylvicolus	11	178.9 (165-194)	18-22	8.7-12.3	32-48	10	116	E
telloi	2	261.5 (260-263)	24-26	12.7-14.8	59-67	12	177	E
wilsoni	2	293.5 (287-300)	47-49	5.3-6.3	51-67	10	101	E

diagnostic characteristics (see Table 1) and head scutellation, and the senior author has no doubt that they represent conspecific races. The primary distinguishing characteristics that separate *L. gestri* from *L. sundewalli* are a completely divided nasal, a lower number of middorsals (202 vs. 238-286), and a slightly longer tail (L/TL ratio 17.5 vs. 18.8-28.0).

Range.- Probably endemic to Fernando Po.

Remarks.- There are few locality records for either race, *L. s. sundewalli* having been recorded from Ghana, Togo, Chad, and Central African Republic, whereas *L. s. gestri* is probably restricted to Fernando Po Island in the Gulf of Guinea. A re-examination of the syntype of *Glauconia gestri* from Buea, Cameroon, in the Genoa Museum will probably reveal it to belong to *L. s. sundewalli*.

Specimen examined (1).- FERNANDO PO: Basile, BMNH 1946.1.17.3.

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CHECKLIST OF THE AMPHIBIANS OF INDIA, WITH ENGLISH COMMON NAMES

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ABSTRACT.- A checklist of the amphibians of India is presented, along with recommended English common names. The Dubois (1992) scheme of classification is followed for members of the family Ranidae. The fauna at present includes 210 species in nine families.

KEY WORDS.- Amphibians, checklist, English common names, biodiversity, India.

INTRODUCTION

Last inventoried by Dutta (1997), the amphibian fauna of Republic of India has seen significant changes since the last monograph by Boulenger (1890), through the accretion of new species and the allocation of several species, particularly of the genus *Rana* (Family Ranidae) to several genera by Dubois (1992). This proposed scheme of classification has found support in the checklist of Duellman (1993), although not all workers have agreed on the generic allocation of all taxa (see Inger, 1996). In this paper, we have attempted to take stock of all known species from India, primarily using the generic classification of Dubois (1992). An English name is included with every species or subspecies we have recognised. For additional information on each taxa, we refer readers to the checklists of Frost (1985), Duellman (1993), and Dutta (1992; 1997).

MEGOPHRYIDAE

1. *Megophrys boettgeri* (Boulenger, 1899): Boettger's pelobatid toad
2. *Megophrys lateralis* (Anderson, 1871): Anderson's pelobatid toad
3. *Megophrys montana* Kuhl & Van Hasselt, 1822: Montane pelobatid toad
4. *Megophrys parva* (Boulenger, 1893): Myanmar pelobatid toad
5. *Megophrys robusta* (Boulenger, 1908): Robust pelobatid toad
6. *Scutiger nyingchinensis* Fei, 1977: Ladakh pelobatid toad
7. *Scutiger occidentalis* Dubois, 1977: Western pelobatid toad
8. *Scutiger sikimmensis* (Blyth, 1854): Sikkimese pelobatid toad

BUFONIDAE

9. *Ansonia kamblei* Ravichandran, 1992: Maharashtra stream toad
10. *Ansonia ornata* Günther, 1875: Ornate stream toad
11. *Ansonia rubigina* Pillai & Pattabiraman, 1981: Red stream toad
12. *Bufo abatus* Ahl, 1925: Ahl's toad
13. *Bufo beddomii* Günther, 1875: Beddome's toad
14. *Bufo brevirostris* Rao, 1937: Short-nosed toad
15. *Bufo fergusonii* Boulenger, 1892: Ferguson's toad
16. *Bufo himalayanus* Günther, 1894: Himalayan toad
17. *Bufo hololius* Günther, 1875: Gnther's toad
18. *Bufo koynaensis* Soman, 1963: Koyna toad
19. *Bufo latestii* Boulenger, 1882: Lataste's toad
20. *Bufo melanostictus* Schneider, 1799: Common Asian toad
21. *Bufo microtympanum* Boulenger, 1882: Small-eared toad
22. *Bufo parietalis* Boulenger, 1882: Ridged toad
23. *Bufo silentvalleyensis* Pillai, 1981: Silent Valley toad

24. *Bufo stomaticus* Lütken, 1862: Marbled toad
25. *Bufo stuarti* Smith, 1929: Stuart's toad
26. *Bufo viridis* Laurenti, 1768: Green toad
27. *Bufoides meghalayana* (Yazdani & Chanda, 1971): Khasi Hills toad
28. *Pedostibes kempi* (Boulenger, 1919): Garo Hills tree toad
29. *Pedostibes tuberculosus* Günther, 1875: Malabar tree toad

MICROHYLIDAE

30. *Kaloula baleata* (Müller, 1836): Brown bullfrog
    Kaloula baleata ghoshi Cherchi, 1954: Andaman Island bullfrog
31. *Kaloula pulchra* Gray, 1831: Painted bullfrog
32. *Kaloula taprobanica* Parker, 1934: Sri Lankan bullfrog
33. *Melanobatrachus indicus* Beddome, 1878: Malabar black narrow-mouthed frog
34. *Microhyla berdmorei* (Blyth, 1856): Berdmore's narrow-mouthed frog
35. *Microhyla chakrapani* Pillai, 1977: Chakrapani's narrow-mouthed frog
36. *Microhyla heymonsi* Vogt, 1911: Heymons' narrow-mouthed frog
37. *Microhyla ornata* (Duméril & Bibron, 1841): Ornate narrow-mouthed frog
38. *Microhyla rubra* (Jerdon, 1854): Red narrow-mouthed frog
39. *Micryletta inornata* (Boulenger, 1890): False ornate narrow-mouthed frog
40. *Ramanella anamalaiensis* Rao, 1937: Anaimalai Ramanella
41. *Ramanella minor* Rao, 1937: Small Ramanella
42. *Ramanella montana* (Jerdon, 1854): Jerdon's Ramanella
43. *Ramanella mormorata* Rao, 1937: Marbled Ramanella
44. *Ramanella triangularis* (Günther, 1875): Malabar Ramanella
45. *Ramanella variegata* (Stoliczka, 1872): Variegated Ramanella
46. *Uperodon globulosus* (Günther, 1864): Grey balloon frog
47. *Uperodon systoma* (Schneider, 1799): Marbled balloon frog

RANIDAE

48. *Amolops afghanus* (Günther, 1858): Meghalaya stream frog
49. *Amolops chakrataensis* Ray, 1992: Dehradun stream frog
50. *Amolops formosus* (Günther, 1875): Beautiful stream frog
51. *Amolops gerbillus* (Annandale, 1912): Gerbill stream frog
52. *Amolops jaunsari* Ray, 1992: Jaunsar stream frog
53. *Amolops monticola* (Anderson, 1871): Montane stream frog
54. *Amolops senchalensis* (Chanda, 1986): Senchal stream frog
55. *Chaparana sikimensis* (Jerdon, 1870): Sikkimese frog
56. *Euphlyctis cyanophlyctis* (Schneider, 1799): Indian skipping frog
57. *Euphlyctis ghoshi* (Chanda, 1990): Ghosh's frog
58. *Euphlyctis hexadactylus* (Lesson, 1834): Indian green frog
57. *Hoplobatrachus crassus* (Jerdon, 1853): Jerdon's bull frog
58. *Hoplobatrachus tigerinus* (Daudin, 1803): Indian bull frog
59. *Indirana beddomii* (Günther, 1875): Beddome's frog
60. *Indirana brachytarsus* (Günther, 1875): Leaf-hopper frog
61. *Indirana diplostictus* (Günther, 1875): Rufous leaf-hopper frog
62. *Indirana gundia* (Dubois, 1985): Gundia frog
63. *Indirana leithii* (Boulenger, 1888): Leith's frog
64. *Indirana leptodactyla* (Boulenger, 1882): Long-toed frog
65. *Indirana phrynoderma* (Boulenger, 1853): Toad-skinned frog
66. *Indirana semipalmata* (Boulenger, 1882): Small-handed frog
67. *Indirana tenuilingua* (Rao, 1937): Slender-tongued frog

68. *Limnonectes andamanensis* (Stoliczka, 1870): Andaman frog
69. *Limnonectes brevipalmata* (Peters, 1871): Short-webbed frog
70. *Limnonectes cancrivorus* (Gravenhorst, 1829): Crab-eating frog
71. *Limnonectes doriae* (Boulenger, 1887): Doria's frog
72. *Limnonectes keralensis* (Dubois, 1980): Kerala warty frog
73. *Limnonectes khasiana* (Anderson, 1871): Khasi Hills frog
74. *Limnonectes kuhlii* (Tschudi, 1838): Kuhl's creek frog
75. *Limnonectes laticeps* (Boulenger, 1882): Flat-headed frog
76. *Limnonectes limnocharis* (Boie in: Wiegmann, 1835): Cricket frog
77. *Limnonectes mawlindipi* (Chanda, 1990): Mawlindip frog
78. *Limnonectes mawphlangensis* (Pillai & Chanda, 1977): Mawphlang frog
79. *Limnonectes murthii* (Pillai, 1979): Murthy's frog
80. *Limnonectes nilagiricus* (Jerdon, 1853): Nilgiri frog
81. *Limnonectes orissaensis* Dutta, 1997: Orissa frog
82. *Limnonectes parambikulamana* (Rao, 1937): Parambikulam frog
83. *Limnonectes sauriceps* (Rao, 1937): Lizard-headed frog
84. *Limnonectes shompenorum* Das, 1996: Shompen frog
85. *Limnonectes syhadrensis* (Annandale, 1919): Syhadra frog
86. *Micrixalus fuscus* (Boulenger, 1882): Dusky torrent frog
87. *Micrixalus gadgili* Pillai & Pattabiraman, 1991: Gadgil's torrent frog
88. *Micrixalus nudis* Pillai, 1978: Naked torrent frog
89. *Micrixalus phyllophila* (Jerdon, 1853): Pink-thighed torrent frog
90. *Micrixalus saxicolus* (Jerdon, 1853): Small torrent frog
91. *Micrixalus silvaticus* (Boulenger, 1882): Forest torrent frog
92. *Micrixalus thampii* Pillai, 1981: Thampi's torrent frog
93. *Nanorana pleskei* Günther, 1896: Pleske's high altitude frog
94. *Nyctibatrachus aliciae* Inger, Shaffer, Koshy & Bakde, 1984: Grandison's wrinkled frog
95. *Nyctibatrachus beddomii* (Boulenger, 1882): Pigmy wrinkled frog
96. *Nyctibatrachus kempholeyensis* (Rao, 1937): Kempholey wrinkled frog
97. *Nyctibatrachus deccanensis* Dubois, 1984: Deccan wrinkled frog
98. *Nyctibatrachus humayuni* Bhaduri & Kripalani, 1955: Abdulali's wrinkled frog
99. *Nyctibatrachus major* Boulenger, 1882: Large wrinkled frog
100. *Nyctibatrachus minor* Inger, Shaffer, Koshy & Bakde, 1984: Small wrinkled frog
101. *Nyctibatrachus sanctipalustris* Rao, 1920: Sacred swamp wrinkled frog
102. *Nyctibatrachus sylvaticus* Rao, 1937: Forest wrinkled frog
103. *Nyctibatrachus vasanthi* Ravichandran, 1997: Kalakad wrinkled frog
104. *Occidozyga lima* (Gravenhorst, 1829): Puddle frog
105. *Paa hazarensis* (Dubois & Khan, 1979): Hazara frog
106. *Paa liebigii* (Günther, 1860): Liebig's frog
107. *Paa minica* (Dubois, 1975): Tiny frog
108. *Paa sternosignata* Murray, 1885: Murray's frog
109. *Phrynoglossus borealis* Annandale, 1912: Northern frog
110. *Rana alticola* Boulenger, 1882: High altitude frog
111. *Rana annandalii* Boulenger, 1920: Annandale's frog
112. *Rana assamensis* Sclater, 1892: Assamese frog
113. *Rana aurantiaca* Boulenger, 1904: Golden frog
114. *Rana blanfordii* Boulenger, 1882: Blanford's frog
115. *Rana chalconota* (Schlegel, 1837): Copper-cheeked frog
116. *Rana charlesdarwini* Das, 1998: Charles Darwin's frog

117. *Rana curtipes* Jerdon, 1853: Bicoloured frog
118. *Rana danieli* Pillai & Chanda, 1977: Daniel's frog
119. *Rana erythraea* (Schlegel, 1837): Leaf frog
120. *Rana garoensis* Boulenger, 1920: Garo Hills frog
121. *Rana khare* (Kiyasetuo & Khare, 1986): Indian flying frog
122. *Rana leptoglossa* (Cope, 1868): Long-tongued frog
123. *Rana livida* (Blyth, 1855): Bright frog
124. *Rana malabarica* Tschudi, 1838: Fungoid frog
125. *Rana nicobariensis* (Stoliczka, 1870): Nicobarese frog
126. *Rana nigrovittata* (Blyth, 1855): Black-spotted frog
127. *Rana taipehensis* Van Denburgh, 1909: Taipeh frog
128. *Rana temporalis* Günther, 1864: Bronzed frog
129. *Rana vicina* Stoliczka, 1872: Stoliczka's frog
130. *Taylorana hascheanus* (Stoliczka, 1870): Hasche's frog
131. *Tomopterna breviceps* (Schneider, 1799): Short-headed burrowing frog
132. *Tomopterna dobsonii* (Boulenger, 1882): Dobson's burrowing frog
133. *Tomopterna leucorhynchus* (Rao, 1937): Rao's burrowing frog
134. *Tomopterna rolandae* Dubois, 1983: Roland's burrowing frog
135. *Tomopterna rufescens* (Jerdon, 1854): Reddish burrowing frog

HYLIDAE

136. *Hyla annectans* Jerdon, 1870: Indian hylid frog

RHACOPHORIDAE

137. *Chirixalus doriae* Boulenger, 1893: Doria's tree frog
138. *Chirixalus dudhwaensis* Ray, 1992: Dudhwa tree frog
139. *Chirixalus simus* Annandale, 1915: Annandale's tree frog
140. *Chirixalus vittatus* (Boulenger, 1887): Boulenger's tree frog
141. *Philautus andersoni* (Ahl, 1927): Anderson's bush frog
142. *Philautus annandalii* (Boulenger, 1906): Annandale's bush frog
143. *Philautus beddomii* (Günther, 1875): Beddome's bush frog
144. *Philautus bombayensis* (Annandale, 1919): Maharashtra bush frog
145. *Philautus chalazodes* (Günther, 1875): White-spotted bush frog
146. *Philautus charius* Rao, 1937: Seshachar's bush frog
147. *Philautus cherrapunjiae* Roonwal & Kripalani, 1961: Cherrapunji bush frog
148. *Philautus crnri* Dutta, 1985: Rao's bush frog
149. *Philautus elegans* Rao, 1937: Crimson bush frog
150. *Philautus femoralis* (Günther, 1864): Plain green bush frog
151. *Philautus flaviventris* (Boulenger, 1882): Yellow-bellied bush frog
152. *Philautus garo* (Boulenger, 1919): Garo Hills bush frog
153. *Philautus glandulosus* (Jerdon, 1853): Rough-skinned bush frog
154. *Philautus hassanensis* Dutta, 1985: Hassan bush frog
155. *Philautus kempiae* (Boulenger, 1919): Kemp's bush frog
156. *Philautus kottigeharensis* Rao, 1937: Kottigehar bush frog
157. *Philautus leucorhinus* (Lichtenstein & Martens, 1856): White-nosed bush frog
158. *Philautus melanensis* Rao, 1937: Black bush frog
159. *Philautus namdaphaensis* Sarkar & Sanyal, 1985: Namdapha bush frog
160. *Philautus narainensis* Rao, 1937: Naraina's bush frog
161. *Philautus noblei* (Ahl, 1927): Noble's bush frog
162. *Philautus parkeri* (Ahl, 1927): Parker's bush frog
163. *Philautus pulcherimus* (Ahl, 1927): Beautiful bush frog

164. *Philautus sanctisilvaticus* Das & Chanda, 1997: Sacred grove bush frog
165. *Philautus shillongensis* Pillai & Chanda, 1973: Xmas bush frog
166. *Philautus shyamrupus* Chanda & Ghosh, 1989: Shyamrup's bush frog
167. *Philautus signatus* (Boulenger, 1882): Quartet bush frog
168. *Philautus swamianus* Rao, 1937: Ramaswami's bush frog
169. *Philautus temporalis* (Günther, 1864): Dark-eared bush frog
170. *Philautus terebrans* Das & Chanda, 1998: Boring bush frog
171. *Philautus travancoricus* (Boulenger, 1891): Travancore bush frog
172. *Philautus variabilis* (Günther, 1868): Variable bush frog
173. *Polypedates insularis* Das, 1995: Nicobarese tree frog
174. *Polypedates leucomystax* Gravenhorst, 1829: Six-lined tree frog
    Polypedates leucomystax teraiensis (Dubois, 1986): Terai tree frog
175. *Polypedates maculatus* (Gray, 1834): Indian tree frog
    Polypedates maculatus maculatus (Gray, 1834): Common Indian tree frog
    Polypedates maculatus himalayensis Annandale, 1912: Himalayan tree frog
176. *Polypedates pseudocruciger* Das & Ravichandran, 1998: False hour-glass tree frog
177. *Rhacophorus appendiculatus* (Günther, 1859): South-east Asian tree frog
178. *Rhacophorus bipunctatus* Ahl, 1927: Twin spotted tree frog
179. *Rhacophorus bisacculus* Taylor, 1962: Taylor's tree frog
180. *Rhacophorus calcadensis* Ahl, 1927: Kalakkad tree frog
181. *Rhacophorus dubius* Boulenger, 1882: Boulenger's tree frog
182. *Rhacophorus jerdonii* (Günther, 1875): Jerdon's tree frog
183. *Rhacophorus lateralis* Boulenger, 1883: Small tree frog
184. *Rhacophorus malabaricus* Jerdon, 1870: Malabar gliding frog
185. *Rhacophorus maximus* Günther, 1858: Large tree frog
186. *Rhacophorus namdaphaensis* Sarkar & Sanyal, 1985: Namdapha tree frog
187. *Rhacophorus naso* Annandale, 1912: Uphill tree frog
188. *Rhacophorus pleurostictus* (Günther, 1864): Zamorin tree frog
189. *Rhacophorus reinwardtii* (Schlegel, 1840): Reinwardt's tree frog
190. *Rhacophorus taeniatus* Boulenger, 1906: Terai tree frog
191. *Rhacophorus tuberculatus* (Anderson, 1871): Tuberculate tree frog
192. *Theloderma asper* (Boulenger, 1886): Warty tree frog
193. *Theloderma moloch* (Annandale, 1912): Eerie tree frog

ICHTHYOPHIIDAE

194. *Ichthyophis beddomei* Peters, 1879: Beddome's caecilian
195. *Ichthyophis bombayensis* Taylor, 1960: Maharashtra caecilian
196. *Ichthyophis longicephalus* Pillai, 1986: Long-headed caecilian
197. *Ichthyophis malabarensis* Taylor, 1960: Malabar caecilian
198. *Ichthyophis peninsularis* Taylor, 1960: Kerala caecilian
199. *Ichthyophis sikkimensis* Taylor, 1960: Sikkimese caecilian
200. *Ichthyophis subterrestris* Taylor, 1960: Semi-terrestrial caecilian
201. *Ichthyophis tricolor* Annandale, 1909: Three-coloured caecilian
202. *Uraeotyphlus malabaricus* (Beddome, 1870): Malabar caecilian
203. *Uraeotyphlus menoni* Annandale, 1913: Menon's caecilian
204. *Uraeotyphlus narayani* Seshachar, 1939: Narayan's caecilian
205. *Uraeotyphlus oxyurus* (Duméril & Bibron, 1841): Sharp-tailed caecilian

CAECILIIDAE

206. *Gegeneophis carnosus* (Beddome, 1870): Blind caecilian

207. *Gegeneophis fulleri* (Alcock, 1904): Fuller's caecilian
208. *Gegeneophis ramaswamii* Taylor, 1964: Ramaswami's caecilian
209. *Indotyphlus battersbyi* Taylor, 1960: Battersby's caecilian

SALAMANDRIDAE

210. *Tylototriton verrucosus* Anderson, 1871: Himalayan newt

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Notes on Growth and Maturity in *Python molurus molurus*

Sayaji Baug Zoo, Vadodara, Gujarat, India has been successfully breeding the Indian rock python (*Python molurus molurus*) since 1991.The first batch of seven hatchlings were maintained for studies on growth and maturity. Each individual was maintained separately in 75 x 55 x 65 cm glass-fronted wooden cages.They were sexed by probing and identified by their blotch pattern.

Snakes were fed on small mice during the first three months and on rats on subsequent months of the first year. Pigeons and small chickens were fed in the second and third year. In subsequent years, they were fed only on chickens. Food was offered at intervals of four to six days during the warmer months, and up to 15-20 days during the cooler months.

Data taken every six months include total body length (TBL) and body weight (BW).The same measurements were also taken before mating.Three years growth data have already been analysed (Vyas, 1995). Observations on python (sex ratio 2:4) growth and maturity are presented.

All hatchlings mean total body length had reached ca. 2 m at the end of 42 months, on January, 1995. Four pairs were obtained (Table 1) from the breeding, using two extra males, in the first week of February, 1995.

Pair 1: The first mating was observed on 20 February. Unfortunately, the female was found dead on 26 February, without any discernable signs of illness. During post-mortem, both ovaries were found fully developed with eight yellow ova measuring 2.5-3 cm.

Pair 2: The female P2F was introduced into the male enclosure (3 x 3 x 3 m of concrete cement room) for further observations. The first mating was observed on 9 February, 1995 and on the same day the male had swallowed the female. After two days, the male voided the partially digested female. A few ovarian follicles and fully developed ovaries were observed in the dissected female.

Pair 3: During 1995, no remarkable behaviour or mating in the pair were observed. The female was introduced to another male in the mating season of 1996. A total of four matings were observed on 11, 13, 14, and 16 March, 1996. She laid eight eggs on 12 May, 1996, which were oblong, capsule-shaped with average dimensions 9.31 x 3.93 cm and weight 78.12 gm, yellow lacking a calcareous shell.

Pair 4: Continuously during two mating seasons (February to March, 1995 and 1996), the male was introduced to the female, but only one mating was observed on 21 March, 1996. However, the female did not lay eggs during the season. The same pair was again observed in the first week of February, 1997 and eight matings occurred between 24 February and 5 April, 1997. She laid seven eggs on 11 June, 1997, of which five lacked calcareous shells (dimensions 9.41 x 3.99 cm and 86 gm in weight), the remaining two fully developed with white calcareous shell (dimensions 13.05 x 5.27 cm and 230 gm in weight).

The present studies show that females can attain sexual maturity between 43-67 months and males at 67 months. According to Acharjyo and

TABLE 1: Measurements (taken in January, 1995; length in cm; weight in kg) of four pairs of *Python molurus molurus*. Wild caught animals asterisked.

Pair No.	Female identification code Total body length (TBL)/Body weight (BW)	Male identification code Total body length (TBL)/Body weight (BW)
1	P1F or 00M mark TBL=219.0/BW=5.0	Tiny M* TBL=200.0/BW=3.0
2	P2F or BAT-N mark TBL=208.5/BW=5.5	Blind M* TBL=246.0/BW=9.0
3	P3F or zigzag mark TBL=207.5/BW=4.5	P6M or Long M TBL=157.5/BW=3.0
4	P4F or four dumble mark TBL=183.0/BW=3.0	P5M or 0000 mark TBL=190.0/BW=3.0

TABLE 2: Summarized data of *Python molurus molurus* from birth to maturity. Abbreviations are as follows: TBL= total body length; BW= body weight; L= length; W= weight.

Identification code number	Measurements at birth 15.07.91		Measurements at maturity		Date of mating/ ovulation	Hatchling rate time		Age at maturity (months)	Remarks
	TBL (cm)	BW (cm)	TBL (cm)	BW (cm)		L (cm)	W (gm)		
P1F	66.0	135.0	219.0	5.0	20.02.95	3.31	37.03	43.11	female died on 26.02.95
P2F	59.0	140.0	208.5	5.5	09.02.95	3.50	39.28	42.24	eaten by male on 09.02.95
P3F	56.5	135.0	243.0	7.3	13.03.96	4.30	54.07	55.28	female laid eight shelles eggs on 12.05.96
P4F	60.2	135.0	225.5	6.1	24.02.97	3.74	45.18	67.09	female laid seven eggs on 11.06.98, five of which were shelless
P5M	66.0	140	235.0	5.2	24.02.97	3.56	37.14	67.09	

Mishra (1980), females reach sexual maturity at about 43 months, males requiring a longer time.

Sexual maturity in reptilian species is thought related to the size of the animal, rather than to age. (Hildebrand, 1932; Cagle, 1948; Verma and Sahi, 1996; Vyas, 1996, 1997). Mature animal size is correlated to hatchling size, as also reported by Andrew (1982), who compared maximum rate of growth to hatchling length in 17 species of snakes and found that growth rate was significantly higher in species with larger hatchlings. Relative growth from hatchlings to minimum mature length (approximate length at first ovulation) in female snakes was observed by Parker and Plummer (1987) in a few species of colubrid and elapid snakes, which showed that the largest elapids reach maturity when their length tripled. The present data on relative growth from hatchling to minumum maturity in females (length 3.30-4.30 m and weight 3.03-54.07 gm), indicate that even though the female P4F laid eggs at the age of 67 months, her relative growth rate was 3.74 times its length and 45.18 times its weight (Table 2).

Ross and Marzec (1990) assumed that pythons can reach (300 cm) length within a year if fed well and can reach sexual maturity between 18-24 months, suggesting that sexual maturity is more closely related to body size.

In summary, sexual maturity of *Python molurus molurus* is related to size and not to age, female python hatchlings reaching sexual maturity at over 3.72-3.82 times their length. Male pythons attain maturity later but at about the same size, because relative growth rate is slower than that of the female. Increase in lengths of female hatchlings reflects sexual maturity, while increase in weight is considered to be associated with reproductive condition (Table 3).

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TABLE 3: Comparative data on relative growth rate of mature female *Python molurus molurus* from two zoos. Data for animals from Nandankanan Biological Park are from Acharjyo and Mishra (1980).

Area	Sample size	Measurements at birth		Measurements at maturity		Growth rate at maturity		Age at maturity (months)	Clutch size (range)	Remarks
		TBL (cm)	BW (gm)	TBL (cm)	BW (gm)	L	W			
Sayaji Baug Zoo, Vadodara, Gujarat	4	60.10	136.70	223.75	5955	3.72	43.70	43 - 67	7.5 (8-7)	two normal eggs
Nandankanan Biological Park, Bhubaneswar, Orissa	2	61.71	90.29	242.50	8335	3.92	92.31	43	15 (13-17)	ten normal eggs

erence to age at first egg-laying. *J. Bombay nat. Hist. Soc.* 77: 344-350.

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Using Passive Integrated Transponders to study the Ecology of *Laticauda colubrina*

The yellow-lipped sea krait (*Laticauda colubrina*) was studied in the Andaman Islands, India, between December, 1996 and April 1997. These marine snakes come ashore to complete digestion, to moult and to nest. Nonetheless, nesting sites of sea kraits have not yet been located in the Andamans. Of the two species of sea kraits (genus *Laticauda*) known from the Andaman Islands, *L. colubrina* is by far more common than *L. laticaudata*. Aspects of their biology have been studied by Herre and Rabor (1949), Saint Girons (1964) in New Caledonia and Klemmer (1967), Pernetta (1977) and Guinea (1981) in Malaysia, Fiji and the Philippines. In the Andaman Islands, studies aimed at quantifying behavioural aspects such as landward and seaward movements of these snakes, time spent on land, habitat and microhabitat preference, have been conducted (Shetty and Prasad, 1996).

The present study represents the first known use of PIT tags (tags and scanner supplied by the AVID Tag Company) on sea snakes. The objectives were:

- To tag sea kraits using Passive Integrated Transponder (PIT) tags and test the effectiveness of this marking method on sea snakes and also to obtain a population estimate around South Reef Island.
- To initiate studies on growth rates of individual snakes.
- To identify sites harbouring populations to conduct studies on movement and map their distribution.
- To survey the Andaman Islands for suitable sites for more detailed studies on sea krait ecology.
- To obtain baseline data on the terrestrial microhabitats of the snakes.

Tagging, measurements and data on habitat use were obtained from South Reef Island, off the North Andamans (area 117 ha; 12° 46'N; 29° 39'E). All islands in North Andamans group,

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- To survey the Andaman Islands for suitable sites for more detailed studies on sea krait ecology.
- To obtain baseline data on the terrestrial microhabitats of the snakes.

Tagging, measurements and data on habitat use were obtained from South Reef Island, off the North Andamans (area 117 ha; 12° 46'N; 29° 39'E). All islands in North Andamans group,

TABLE 1: Tag numbers of *Laticauda colubrina* tagged at South Reef Island.

S. No.	Tag No.	S. No.	Tag No.	S. No.	Tag No.
1	024-638-870	19	024-866-274	37	024-859-020
2	025-118-285	20	025-119-305	38	025-360-025
3	025-300-350	21	024-803-518	39	025-117-093
4	024-860-536	22	025-274-594	40	024-823-278
5	025-274-630	23	025-543-043	41	024-862-792
6	025-541-048	24	024-809-071	42	025-588-621
7	025-811-051	25	025-637-818	43	025-058-626
8	025-269-879	26	024-845-583	44	025-060-572
9	024-857-844	27	025-032-593	45	025-091-284
10	025-584-041	28	025-568-093	46	025-516-830
11	025-302-370	29	025-536-300	47	025-541-308
12	025-272-602	30	025-081-617	48	025-518-258
13	024-887-795	31	025-096-036	49	025-810-067
14	025-087-013	32	025-350-290	50	025-515-809
15	025-060-032	33	025-062-354	51	025-590-533
16	025-303-338	34	025-277-845	52	025-276-574
17	025-344-002	35	024-638-318	53	024-809-567
18	024-634-070	36	025-058-800	54	025-279-289

from South Reef through Landfall Island to South Island, were surveyed to check for the presence/absence of snakes.

PIT (Passive Integrated Transponder) tags are small glass-encapsulated microchip transponders, which have been used to identify individual animals. These tags are injected subcutaneously, intra-muscularly, or intra-abdominally using a modified hypodermic syringe, and are encoded with individual numeric codes that can be read with an external scanning device. These tags have been used extensively on amphibians and reptiles and their usefulness has been discussed in Jemison et al. (1995). The effects of PIT tagging on growth, movement patterns and recapture probability, were assessed by Hemison et al. (1995), who confirmed that these tags do not have any impact on the above aspects in *Sistrurus miliarius*.

TABLE 2: Tag numbers of recaptured *Laticauda colubrina* at South Reef Island.

S. No.	Ref. No.	Tag No.	S. No.	Ref. No.	Tag No.
1	51	025-290-533	7	38	025-360-025
2	41	024-862-792	8	49	025-810-067
3	28	025-568-093	9	29	025-536-300
4	2	025-118-285	10	40	024-823-278
5	23	025-543-043	11	19	024-866-274
6	18	025-634-070			

This is the first time these tags are being used for sea snakes. Hence, only a few snakes were tagged, to verify the effectiveness and safety of this method for sea snakes. PIT tags were sterilized in alcohol and injected subcutaneously, on the left side posterior to the cloaca, at the junction of the dorsal and ventral scales of the tail.

The beach was patrolled every night at intervals of about an hour, starting from 1800 hours until about 0200 hours. Sea kraits coming up onto the island and those going down to the sea, were caught and scanned for tags. Fifty-four snakes were marked on South Reef Island between 12-24 January, 1997. The untagged snakes were tagged and morphometric measurements recorded. Snakes were then released and almost all the snakes continued in the same direction as before, though a few land-bound snakes returned to the sea on being released.

Data recorded for each individual were: serial number, date, time, PIT tag number, direction of movement, sex, snout-vent length, tail length, width of dark bands at the neck, midbody and tail

TABLE 3: Morphometric data of tagged *Laticauda colubrina* at South Reef Island. References and definitions: M = males (n = 31); F = females (n = 24); SVL = snout-vent length; TL = tail length; TBL = total body length; % tail = percentage of tail length to total boody length; BW = width of dark band; girth (N, B and T) = girth at neck, midbody and base of tail. All measurements in cm, except BW which is in mm; weight in gm.

	Mean		± S.D.		Minimum		Maximum		Mode	
	M	F	M	F	M	F	M	F	M	F
SVL	84.56	139.52	10.30	14.36	58.00	114.00	104.90	161.50		
TL	11.94	13.29	1.31	1.41	8.50	10.20	15.00	16.00		
TBL	96.50	152.81	10.37	15.19	70.00	124.20	116.70	175.90		
% tail	12.50	8.73	1.82	0.77	8.06	6.76	17.14	10.41		
Mean BW	9.77	13.63	0.99	2.53	7.25	7.37	11.98	17.48		
Girth (N)	4.27	7.85	0.38	2.13	3.60	4.30	4.90	15.20		
Girth (B)	6.95	12.36	0.94	2.94	5.70	6.30	9.00	19.40		
Girth (T)	4.54	7.52	0.40	1.71	4.00	4.50	5.80	12.80		
Mean girth	5.25	9.24	0.48	2.02	4.60	5.03	6.43	15.80		
Dorsal	23	25	0.93	0.72	19	23	25	25	23	25
Subcaudal	42	34	2.91	2.61	33	29	44	43	44	34
Weight	247	1159	59.56	436.95	175	210	435	2160		
Bands	40	40	2.59	2.12	35	37	46	44	39	41

length, girth at the neck, midbody and tail, number of dorsal scales, number of subcaudal scales, weight, number of dark bands, number and location of half-bands, parasite load, number, location and description of scars, tail notches, and other unusual marks. The temperatures of resting sites of the snakes on land were recorded for a few sites on South Reef Island, every two hours over 24 hour periods, using digital and dial thermometers.

Apart from the study on South Reef Island, several parts of the Andaman group of islands were surveyed for the presence of sea snakes, with the objective of identifying sites for future studies. In the case of small islands, the entire island was surveyed by foot, and on large islands, selected stretches of sandy beach and rocky coast were searched. On islands where the snakes were not actually seen, but traces of their presence (such as characteristic tracks on sandy beaches, sloughs and faeces near likely resting sites) found, these were considered as conclusive evidence of the use of the island by sea snakes. Islands with 30 or more tracks were considered to be feasible sites to monitor movements in future. The number of tracks on the sand on any given day represents the approximate number of movements in the past week as track remain distinct for a minimum period of one week.

The tag numbers of the snakes tagged on South Reef Island between 12-24 January, 1997 are given in Table 1.

The number of snakes tagged was restricted, since the tagging was an experiment to check the effectiveness and longivity of PIT tags on sea snakes.

South Reef Island was revisited between 27 February and 10 March, 1997. Using the same sampling effort, 66 snakes were caught, of which 11 were previously tagged. The tagged snakes showed no sign of any damage due to the tag. The ratio of tagged snakes in the recapture sample suggests a population of about 324 in the South Reef Island area. However, the sample size is too small to provide an accurate estimate. The same type of study needs to be conducted during various seasons to obtain a more accurate estimate.

The tag numbers of the 11 recaptured snakes are in Table 2.

Three snakes (serial no. 4, 5, and 7) were each recaptured twice during this period. Summaries of the morphometric data collected for the 54 snakes which were tagged are given in Table 3.

The temperatures of 16 resting sites of Laticauda colubrina were measured. A summary of the temperature data is given in Table 4. Since

the number of thermometers available was limited, the number of readings was restricted.

The survey of islands for presence of sea kraits revealed that the species is widespread in the Andamans group. *Laticauda colubrina* is commonly found in all parts of the Andamans, and *L. laticaudata* is relatively rare. Islands which were found to have considerable populations of sea kraits and which may be potential study sites in the future, considering all practical aspects, are South Reef Island, Latouche Island, Snark Island, Sound Island, Grub Island, Roc Ribs, Twin Island and a few others. Laticauda laticadata was sighted in Grub Island and off Craggy Island.

Since PIT tags are permanent tags, the data on morphometrics got from this study can serve as a baseline data for further studies, especially those related to establishing growth rate.

In a study conducted between December 1995 and January 1997, snakes were observed resting between open buttresses of trees. However, during the present study, which was conducted during the same season (December 1996 to March 1997) and in the same island, there were practically no snakes resting between buttresses of trees. This is probably due to higher mean temperatures this season. This requires further investigation, and it is possible that selection of resting sites by *Laticauda colubrina* depends on the ambient temperature.

TABLE 4: Temperatures of 16 resting sites of *Laticauda colubrina* at South Reef Island.

	Mean	± S.D.	Min.	Max.	Range
Site 1	26.9	1.7	24.5	29.4	4.9
Site 2	27.0	0.8	25.4	28.5	3.1
Site 3	26.6	0.9	25.3	27.8	2.5
Site 4	26.0	1.6	23.9	28.3	4.4
Site 5	27.5	0.3	27.1	28.1	1.0
Site 6	28.5	2.1	25.3	31.6	6.3
Site 7	28.8	3.2	24.9	34.9	10.0
Site 8	27.3	0.8	25.6	28.3	2.8
Site 9	28.7	0.6	27.7	29.4	1.7
Site 10	27.3	1.6	24.2	30.4	6.2
Site 11	27.2	1.4	25.6	29.2	3.6
Site 12	27.0	0.7	26.1	28.2	2.1
Site 13	26.9	0.8	25.7	28.0	2.3
Site 14	26.5	2.1	23.3	29.7	6.4
Site 15	27.4	0.7	26.6	28.6	2.0
Site 16	28.8	1.5	26.6	31.0	4.4

We wish to thank the following people for making this study possible: Richard D'Souza, Chief Wildlife Warden, Andaman and Nicobar Forest Department and the staff of his office for providing us work permit and for cooperation; Harry Andrews, Jennifer Dalty and Romulus Whitaker for procuring the PIT tags, for supporting the study and for useful discussions; Pao Aung, Shewether, Dhanway, Termay, John, Montu, Manish Chandi and others at the ANET base.

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APPENDIX: Morphometric data of tagged *Laticauda colubrina*.

S. No.	Date	Time	Tag No	Dim.	Sex	SVL	TL	Band width	Mean girth	Dorsal	Sub-caudal	Weight	Bands
1	12/01	2015	024-638-870	UU	M	58.0	12.0	9.67		19	42	260	38
2	13/01	1825	025-118-285	UD	F	152.0	16.0	15.17	10.7	25	35	1610	41
3	13/01	1910	025-300-350	DD	F	138.0	12.0	13.23	8.7	23	29	910	43
4	13/01	1950	024-860-536	UU	F	152.0	14.0	14.20	8.5	25	35	1035	40
5	13/01	1955	025-274-630	DD	M	94.0	14.0	9.65	6.0	23		310	41
6	13/01	2210	025-541-048	UU	M	97.0	8.5	6.50	6.2	25	34	310	39
7	13/01	2240	025-811-051	UU	M	71.8	12.1	7.25	5.2	23	38	210	39
8	14/01	1945	025-269-879	UU	M	78.0	12.3	9.32	5.4	23	44	360	44
9	14/01	1955	024-857-844	DD	M	89.3	11.9	8.92	5.0	23	43	185	40
10	14/01	2055	025-584-041	UU	M	84.0	10.2	10.40	4.9	23	44	185	35
11	14/01	2235	025-302-370	UU	F	126.5	13.3	13.02	8.0	25	37	835	42
12	14/01	2245	025-272-602	UU	M	75.5	11.6	9.17	4.9	23	43	235	37
13	15/01	0015	024-887-795	UU	M	80.5	11.9	10.10	5.5	23	44	260	41
14	15/01	1245	025-087-013	LR	F	158.0	14.5	15.72	9.8	25	34	1560	42
15	15/01	1835	025-060-032	UU	F	131.0	12.2	12.42	8.7	24	33	1135	41
16	15/01	1840	025-303-338	UU	F	142.3	15.2	17.48	10.2	25	34	1685	37
17	15/01	1850	025-344-002	UU	M	104.9	11.8	11.98	6.0	25	36	385	41
18	15/01	1840	024-634-070	UD	M	97.0	12.1	9.32	4.8	22	43	200	41
19	15/01	1855	024-866-274	UU	M	92.5	12.4	11.23	5.1	23	44	225	39
20	15/01	1855	025-119-305	UU	F	145.5	14.0	11.95	9.5	23	34	1335	38
21	15/01	2240	024-803-518	UU	M	75.4	9.8	8.48	4.9	23	42	200	46
22	16/01	0005	025-274-594	UU	F	114.0	10.2	13.63	7.2	25	34	685	42
23	16/01	1825	025-543-043	DD	M	99.1	13.2	9.58	4.8	23	43	225	42
24	16/01	1840	024-809-071	UU		83.4	12.6	9.70	5.0	23	41	210	40
25	16/01	1945	025-637-818	UU		67.8	11.5	11.38	5.2	23	42	225	37
26	16/01	2045	024-845-583	UU		72.2	11.8	10.27	4.6	23	44	210	46
27	17/01	1945	025-032-893		F	155.5	13.6	16.05	9.3	24		1475	44
28	17/01	2000	025-568-093	UU		78.5	12.3	9.07	5.0	23	41	200	41
29	17/01	2040	025-536-300	U	F	119.1	12.5	14.68	7.3	25	35	675	37
30	18/01	0110	025-081-617			92.5	12.7	9.97	5.4	23	43	250	39
31	18/01	0115	025-096-036		F	158.5	11.5	13.88	8.3	25	30	1100	44
32	18/01	0125	025-350-290			83.0	11.5	8.05	5.8	23	41	285	39
33	18/01	1810	025-062-354	?	M	77.1	11.5	10.18	5.0	23	42	175	42
34	18/01	2005	025-377-845	DD	F	142.2	15.5	15.12	9.6	25	36	1250	37
35	19/01	1925	024-638-318	DD	M	86.3	12.8	9.35	4.7	23	43	225	44
36	19/01	1925	025-058-800	UU	M	92.1	9.0	10.07	5.5	24	33	275	42
37	19/01	2115	024-859-020	UU	M	81.1	13.5	10.35	4.9	23	43	210	40
38	19/01	2120	025-360-025	DD	M	80.2	12.7	9.60	5.4	23	41	285	41
39	19/01	2130	025-117-093	UU	F	123.0	11.5	12.23	6.8	25	36	675	41
40	19/01	2335	024-823-278	UU	F	135.5	13.5	8.87	15.8	25	33	1285	37
41	20/01	1920	024-862-792	DD	M	89.2	12.5	10.38	5.0	23	44	210	41
42	20/01	2000	025-588-621	?	M	88.2	12.6	10.33	4.7	23	44	210	39
43	21/01	1850	025-058-626	?	F	141.0	14.0	16.40	8.5	24	34	1035	40
44	22/01	Day	025-060-572		F	152.1	13.5	16.10	9.3	25	34	1585	41
45	22/01	Day	025-091-284		M	88.5	11.5	10.00	6.4	23	43	435	41

APPENDIX (continued)

S. No.	Date	Time	Tag No.	Dirn.	Sex	SVL	TL	Band width	Mean girth	Dorsal	Sub-caudal	Weight	Bands
46	22/01	Day	025-516-830		F	138.0	13.0	15.45	10.4	25	34	1560	41
47	22/01	Day	025-541-308		F	149.5	14.4	15.08	8.5	25	34	1085	41
48	22/01	Day	025-518-258		F	141.5	13.1	12.63	9.2	25	32	1460	42
49	22/01	Day	025-810-067		F	161.5	14.4	15.72	10.7	25	33	2160	40
50	22/01	Day	025-515-809		F	116.6	11.5	10.97	5.0	23	43	210	39
51	22/01	Day	025-290-533		F	139.0	12.1	9.63	9.9	24	33	735	39
52	22/01	Day	025-276-574		F	116.2	13.5	7.37	12.0	25	34	735	39
53	22/01	1935	024-809-567	U	M	85.4	15.0	9.43	5.7	23	44	335	39
54	22/01	1940	025-279-289	D	M	80.0	11.8	9.80	5.2	23	43	200	39

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Observations on Gnaphosid Spider Preying on *Philautus* species

(with one text-figure)

There are few (e.g., Bhatnagar, 1971) documented reports of arthropod predation of amphibians in India. At Kakachi, Kalakad-Munthanthurai Tiger Reserve, Tamil Nadu, south-western India, in July, 1997, at 2330 hours, I saw a tree frog calling from a leaf at the edge of a road. It was apparently undisturbed by my torch light, and continued calling. A spider was observed below the leaf, that was moving towards the frog. It paused at the edge of the leaf and in a sudden movement, came to the top of the leaf. The frog stopped calling and was seized just below the eye. The spider proceeded to carry the frog under the leaf, presumably away from the glare of the torch light. The frog struggled for a while and after a few seconds, became still. After some time, the spider dropped the frog among the foliage and crawled away.

The frog was identified as a member of the genus *Philautus* (family: Rhacophoridae); the spider as a member of the family Gnaphoside, the members of which are known to be nocturnal that do not build webs and hunt by active foraging (Vijayalakshmi and Ahimaz, 1993).

I thank Karthikeyan Vasudevan of the "Fragmentation Project", run by the Wildlife Institute of India/US Fish and Wildlife Service and S. U. Saravana Kumar for providing logistic support.

FIGURE 1: *Philautus* species caught by a gnaphosid spider (Kakachi, Kalakad Munthanthurai Tiger Reserve, Tamil Nadu, India).

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Notes on Occurrence and Growth in *Geckoella collagalensis* (Beddome, 1870)

The Kollegal ground gecko, *Geckoella collagalensis* (Beddome, 1870) has been reported from Balarangans, Karnataka State, Nilambur, Kerala, State and Borivali, Maharashtra State, in south-western India (Smith, 1935; Sekar, 1991).

While conducting an amphibian survey on 11 October, 1997, two examples of Geckoella collagalensis (an adult male and a juvenile) were collected from Anaikatty (11° 06'N; 76° 45'E), Tamil Nadu State, at the foot of the Western Ghats. They were found during the evening, from the foot of a rocky outcrop. The vegetation at the site includes Pongamia pinnata, Ziziphus mauritiana and Parthenium thickets. The area lies between altitudes 600-700 m above mean sea level, within the Nilgiri Biosphere Reserve catchment area in the Kodungarai River and is part of the Perinaickenpalayam Reserve Forest. In October, the ambient day time temperature was 29° C, dropping to 19° C at night. The relative humidity during the day was 42-55% and at night, 80%. The average annual precipitation was about 1,000-1,200 mm.

On the day of capture, the adult measured: snout-vent length 47.7 mm; tail length 19.5 mm; head length 16.1 mm; head width 9.5 mm and body weight 2.7 gm.

Both geckos were maintained in a glass terrarium of dimensions 0.9 x 0.5 x 0.5 m for studies on growth. The terrarium was provided with sand as substrate, and landscaped (also for concealment) with pieces of bark and dry leaves. Water was provided in a shallow earthen bowl. The terrarium was cleaned daily, the water replaced and temperature and humidity recoded.

The geckos were few thrice a week with live termites (Kalotermidae) and captive bred house crickets (*Acheta domestica*). As followed by Courts (1995) for *Nactus coindermirensis*, all food insects were dusted with Agrimin and Ossopan as vitamin/mineral supplement, prior to being offered. Food was offered in the late evenings, and both lizards fed readily.

TABLE 1: Body weight (Wt., in gm) and total body length (TL; in mm) recorded in two *Geckoella collagalensis* reared at the Coimbatore Zoological Park.

Months	Adult		Juvenile	
	Wt.	TL	Wt.	TL
Oct., 1997	2.7	67.0	0.5	37.5
Nov.., 1997	1.8	67.0	0.6	37.8
Dec., 1997	2.7	67.7	0.7	41.4
Jan., 1998	3.7	68.1	1.9	49.3
Feb., 1998	4.1	68.6	2.2	53.1
Mar., 1998	4.5	69.1	2.6	58.2

Both geckos spent most of the day under the bark, and were most active during dusk. Though housed together, no aggression between the two geckos was observed. The growth rate in the juvenile was relatively rapid (Table 1). The average monthly increase in total length (TL) was 0.4 mm in the adult and 4.14 mm in the juvenile, while the average monthly weight gain in the adult was 0.37 gm, and in the juvenile, 0.42 gm.

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Notes on the Herpetofauna of North Sumatra

(with one text-figure)

Our knowledge of the herpetofauna of Sumatra, the largest of the Indonesian islands, is still fragmentary. Earlier publications largely were based on collections of the past century and the beginning of this century (e.g., Bleeker; 1858; Boulenger, 1890; Van Kampen, 1905). A checklist and identification key for all snakes recorded from Sumatra was published recently by David and Vogel (1996). Manthey and Grossmann (1997) gave an account of the herpetofauna of the Sunda Region, which included Sumatra. However, from a herpetological point of view, many areas within this large island still remain unknown. Unfortunately, as in many other tropical and subtropical regions, natural ecosystems have been drastically reduced in their extent. For instance, in most parts of the fertile plains along eastern Sumatra, lowland forests were converted to rubber and oil palm plantations, a process that is still going on. Up to now, our knowledge of species diversity in these man-made habitats is extremely poor (Inger and Tan, 1996). This note gives a brief account of the species recorded in an oil palm plantation near Cikampak (Aek Torop), supplemented by a list of species from two sites where reptiles are skinned in Cikampak and Rantauprapat, North Sumatra (Fig. 1; for more details see Fritz and Gaulke, 1997; Gaulke et al., 1997).

During a study of the population status and biology of pythons and water monitors in the oil palm estate Aek Torop (Fig. 1) and a telemetric study in the same area, in 1996 and the beginning of 1997 (Erdelen et al., 1997), all amphibian and reptile species observed were recorded.

In Table 1, species are referred to as very common if they were sighted virtually on all field trips; common, if they were sighted in over 50% of the field trips; less common if sighted several times only. If sighted only a few times, number of sightings is given. In Table 2, species which were seen during each visit at sites where reptiles are skinned in larger numbers are referred to as very common, those seen during almost each visit as common, and those only seen in few individuals during some of the visits as less common.

At first view, oil palm plantations with their variety of hiding places, their shady microhabitats and therefore more humid microclimate more closely resemble natural forests compared to other agricultural areas, such as rice fields. Most of the species we recorded are typical inhabitants of man-made environments in southeast Asia. Our data indicate that oil palm plantations offer suitable habitats only to a very limited number of species. None of the endemic forest dwelling species was found. Despite their shady and humid environment, their different microhabitats, and their abundance of major food classes for amphibians and reptiles, such as arthropods and vertebrates, oil palm plantations obviously cannot be considered an adequate substitute habitat for undisturbed or degraded forests. One of the reasons for the low number of species observed, however, may have been the use of pesticides and other chemicals in the plantation. However, this has not been studied.

The large number of large snake species, like *Python curtus*, *Elaphe flavolineata* and *Ophiophagus hannah* was remarkable. However, high rodent population densities may be the reason for this. While most of these large snakes feed on rodents, the king cobra is certainly attracted to these rodent feeding snakes.

Python curtus and *Varanus salvator* had been mainly collected in oil palm plantations. *Python reticulatus* and most of the chelonians seen in the commercial premises of the dealers had been caught in the larger rivers of the area and their surroundings. Besides common species such as *Cuora amboinensis*, *Orlitia borneensis* or *Siebenrockiella crassicollis*, some of the species found are generally considered relatively rare, including *Batagur baska*, *Dogania subplana* and *Manouria emys*. Even although they still occur in the region, it is questionable how long they can withstand the growing pressures from habitat destruction, pollution and collecting for human use.

FIGURE 1: Map of Sumatra, showing the study sites (black triangles). Modified from Fritz and Gaulke (1997: 13; Fig. 1) by H.-P. Fuchs, Herpetofauna, Verlags-GmbH.

TABLE 1: Herpetofauna recorded from the oil palm estate Aek Torop, north Sumatra (May 1996 to February 1997).

Taxon	Abundance	Comments
Bufonidae		
Bufo melanostictus	very common	
Microhylidae		
Kaloula pulchra	very common	
Microhyla heymonsi	2 records	
Ranidae		
Rana erythraea	very common	along ponds and rivers within the plantation
Rana limnocharis	very common	
Rana nicobariensis	common	mainly along rivers within the plantation
Rhacophoridae		
Polypedates leucomystax	less common	
Polypedates macrotis	very common	
Gekkonidae		
Cosymbotus platyurus	very common	only on building within the plantation
Gehyra mutilata	common	mainly in gardens, less often on oil palms
Hemidactylus frenatus	very common	on buildings and oil palms
Scincidae		
Mabuya multifasciata	common	
Sphenomorphus sp.	less common	unidentified
Varanidae		
Varanus s. salvator	common	
Boidae		
Python curtus brongersmai	very common	rarely found outside burrows
Python reticulatus	?	few individuals caught in traps
Colubridae		
Boiga dendrophila melanota	?	no sightings, individuals caught in traps
Dendrelaphis c. caudolineatus	common	
Dendrelaphis p. pictus	common	
Elaphe flavolineata	common	
Macropisthodon flaviceps	4 records	in and along rivers within the plantation
Ptyas korros	1 record	
Xenochrophis trianguligerus	common	in and along swamps and rivers
Zaocys carinatus	less common	
Elapidae		
Naja sumatrana	1 record	
Ophiophagus hannah	relatively common	
Bataguridae		
Cuora amboinensis couro	less common	in rivers and ponds within the plantation

Low herpetological diversity in oil palm plantations and heavy exploitation of species in more or less pristine environments underscore the urgent need for more effective protection of the remaining natural forests in north Sumatra.

We thank the management of the oil palm estate "P.T.P. III Aek Torop" for allowing us to stay in the guesthouse of the plantation. Mr. Acai and Mr. Sudirman generously made it possible to study the specimens in their

TABLE 2: Amphibians and reptiles recorded from two sites where reptiles are skinned at Cikampak and Rantauprapat, north Sumatra (December 1996 to February 1997).

Taxon	Abundance	Comments
Ranidae		
Rana sp. (*Rana macrodon* group)	common	only in Rantauprapat
Varanidae		
Varanus s. salvator	very common	
Varanus rudicollis	rare	only in Rantauprapat
Acrochordidae		
Acrochordus javanicus	less common	
Boidae		
Python curtus	very common	
Python reticulatus	common	
Bataguridae		
Batagur baska	less common	
Cuora amboinensis couro	very common	
Cyclemys dentata	less common	
Cyclemys oldhamii	less common	
Heosemys spinosa	less common	
Notochelys platynota	less common	
Orlitia borneensis	common	
Siebenrockiella crassicollis	common	
Emydidae		
Trachemys scripta elegans	3 records	in Rantauprapat; exotic species
Testudinidae		
Manouria e. emys		
Trionychidae		
Amyda cartilaginea	common	
Dogania subplana	1 record	
Pelochelys cantorii	less common	

commercial premises. The data were collected during studies for a project on water monitors and pythons, financed by the "Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Bonn" and carried out in cooperation with the Federal Agency for Nature Conservation, Germany.

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OSTEOLOGY OF THE REPTILES by Alfred Sherwood Romer. xxvii + 772 pp. Price US$ 96.50. ISBN 0-89464-985-X. Cloth. Reprinted 1997, Krieger Publishing Company, P.O. Box 9542, Melbourne, Florida 32902, USA. email: info@krieger-pub.com

Two generations of biologists have grown up on Romer's Osteology of the Reptiles (originally published by the University of Chicago in 1956). It is therefore gratifying to see a fine reprint of this out-of-print work. This short review of the work is to announce the reprinting of a classic and to inform workers who have not seen it, of its contents.

The book is organised into two sections: the first is on the skeleton of reptiles, and includes an introduction to the nonskeletal organ systems, the skeletal elements, general structure of the skull, and the skull types in various reptile groups, the mandible, the axial skeleton, the limb girdles, the limbs, miscellaneous skeletal elements (such as the middle ear structures, the hyoid, larynx and tracheal rings, dermal armor, gastralia, the turtle shell, sclerotic cartilages and osseous scleral ring and heterotopic bones are cartilages), and finally, dentition. The second part of the book is on the classification and range of reptiles, which includes a brief history of reptilian classification. Diagnosis are provided for fossil and recent subclasses, orders, suborders and families, and each recognised genera under the family listed, with a continental or a subcontinental distribution. The work concludes with a selected bibliography, which is organised by subject (e.g., nervous system and sense organs) as well as higher taxa.

The only negative aspect I feel is the inadequate new preface to the work by Thomas C. LaDuke, Ph. D. This two page section, plus a five page table and references does not do justice to the seminal tome of Romer, and is sadly incomplete. For instance, of the 10 citations given, only two refer to recent groups of reptiles. Further, the reference to Zug (1993) cited in the preface, is missing in the bibliography.

All told, the reprinting to Romer's classic is very welcome indeed, and may many more generations of herpetologists benefit from its presence on their laboratory desks.

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A FIELDGUIDE TO AUSTRALIAN FROGS by John Barker, Gordon Grigg and Michael Tyler. 1996. 420 pp. ISBN 0 949324 61 2. Australian $36.95; Pound Sterling 18.50; US$ 30; Switzerland Fr. 45; French Fr. 185. Available from:Surrey Beatty & Sons., 45 Rickard Road, Chipping Norton, NSW, Australia 2170, fax: (02) 9821-1253; email: surreybeatty@iform.com.au

First published in 1977 (and authored by Barker and Grigg), there was also a 1995 edition of this work. This 1997 edition of the Aussie frog guide illustrates and describes the approximately 200 described species from that wonderful island continent. Written with the "bright 11 year old" in mind, the use of technical terms are minimal, and descriptions use colouration and patterns. Over 250 colour photographs, line drawings and distributional maps are included, and this work is designed for use both in the field as well as in the laboratory or classroom.

Contents include: Evolution, Taxonomy and Zoogeography of Frogs, Biology of Frogs; The Australian Frogs; Collecting, Keeping and Photographing, Selected Bibliography; Glossary; Index of Scientific Names; Index of Common Names.

Highly recommended!

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ADDENDA TO THE BIBLIOGRAPHY OF THE HERPETOLOGY OF THE ANDAMAN AND NICOBAR ISLANDS

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Hamadryad Vol. 22(1) carried a five page bibliography of the herpetology of the Andaman and Nicobar Islands. Since the compilation of the above list, several omissions have come to our notice. In this addenda, we list these as well as publications and reports that have appeared since. As before, papers or reports resulting from research supported by the Centre for Herpetology, or the Andaman and Nicobar Islands Environmental Team (Centre for Island Ecology), have been indicated with asterisks.

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